Escapement Monitoring of Adult Salmon Using Digital Video Technology in the Kwinageese River, 2002

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ABSTRACT

Miller, D. E., R. C. Bocking and B. E. Baxter. 2005. Escapement monitoring of adult salmon using digital video technology in the Kwinageese River 2002. Can. Manuscr. Rep. Fish. Aquat. Sci. 2711: vii + 58 p.

In 2002, underwater digital video technology was used to monitor adult chinook, sockeye, coho salmon and steelhead in the Kwinageese River, British Columbia. This technique used methodology that does not trap or handle any fish, nor does it alter fish movement, as does a typical weir. Fish were directed through a 1.2 m wide video-viewing box containing underwater cameras with the use of a floating weir on a track and trolley system spanning the width of the river. Fish passage through the video viewing box was recorded 24 hours per day with a time-lapse digital video recorder using both traditional time-lapse recording and motion detection recording techniques. Motion detection mode recorded short video clips only when motion, within a specified portion of the video view, exceeded a defined threshold. When fish passage rates were low and motion detection properly configured, this feature saved a great deal of review time. This was the second year of testing digital video technology for this application on the Kwinageese River.

The video system operated continuously from 17 July to 17 October. A two person crew reviewed video daily and counted 1,893 adult chinook, 5,891 adult sockeye, 1,283 adult coho, and 267 adult steelhead. Counts were further broken down as tagged, untagged or unknown tag status for each species in order to determine mark rates for the Nisga'a Fisheries fishwheel program. Additional data were collected on the colour of spagetti tags on sockeye salmon tagged at the lower Nass fishwheels in order to determine sockeye run timing from the lower Nass to the Kwinageese River. Escapement numbers for chinook and steelhead are not considered complete, as the chinook run had already started at project start up and the steelhead run continued after the study end date. Although escapement numbers were likely obtained for the entire upper Kwinageese coho run, these numbers should not be considered total escapement to the Kwinageese as spawning is suspected to take place in Shanalope Creek which is downstream of the counting site. It is also possible there was a second pulse of coho after the study end date. Sockeye escapement numbers are considered complete as the study period encompassed the entire sockeye run.

Accurate adult escapement and mark rate information on the Kwinageese will allow managers to estimate system wide salmon escapement and harvest rates, as well as, egg-fry survival rates when combined with fall hydro-acoustic estimates. Additional run-timing data will assist managers in managing Nass sockeye fisheries to protect weak stocks.

RÉSUMÉ

Miller, D. E., R. C. Bocking and B. E. Baxter. 2005. Escapement monitoring of adult salmon using digital video technology in the Kwinageese River 2002. Can. Manuscr. Rep. Fish. Aquat. Sci. 2711: vii + 58 p.

En 2002 nous avons surveillé les saumons adultes quinnat, rouge, coho ainsi que les truites arc-en-ciel anadromes dans la rivière Kwinageese en colombie britannique à l'aide de la magnétoscopie numérique subaquatique. Cette méthode n'emploie pas de pièges, ne touche aucun poisson et ne modifie pas le déplacement des poissons comme le font les bourdigues. Les poissons passaient dans une boîte vidéo 1.2m de largeur équippée avec des caméras subaquatiques pour les vidéospectateurs, ceçi à l'aide d'une bourdigue flottante sur un système câble porteur et chariot la largeur de la rivière. Nous avons enregistré le passage des poissons à travers la boîte à vidéo 24 heures par jour avec un vidéo-enregistreur magnétique numérique en se servant des techniques d'enregistrement du système chronophotographique et de la détection du roulement. Lorsqu'en mode de détection du roulement de brefs clips vidéo s'enregistraient seulement lorsque le roulement dans une partie spécifique de la vue vidéo excédait un seuil défini. Quand le nombre de poissons était minime et que la détection du roulement était bien configurée cette caractéristique a sauvé beaucoup de temps. C'est la deuxième année d'essais de la magnétoscopie numérique sur la rivière Kwinageese.

Le système vidéo fut en opération continuelle à partir du 17 juillet jusqu'au 17 octobre. Une équipe de deux a revisé le vidéo chaque jour et a compté 1,893 saumons quinnat adultes, 5,891 saumons rouge adultes, 1,283 saumons coho adultes et 267 truites arc-en-ciel anadromes. Les données d'énumération furent analysées une deuxième fois à savoir si chaque espèce était marquée, non-marquée ou si l'état de marque était inconnu, ceci afin de déterminer les taux de marquage pour le programme aux filets rotatifs des pêches Nisga'a. Des données additionelles furent accumulées sur la couleur d'étiquettes 'spaghetti' sur le saumon rouge marqué aux filets rotatifs de la section inférieure de la rivière Nass afin de déterminer la durée de la migration de la section inférieure de la rivière Nass à la rivière Kwinageese. Le total de l'échappée pour les saumon quinnat et les truites arc-en-ciel anadromes est incomplet, car la migration des saumons quinnat était déjà commencée au début du projet et la migration des truites arc-en-ciel anadromes a continuée après la terminaison du projet. Bien que les données de l'échappée ont probablement été obtenues pour la migration entière des saumons coho de la partie supérieure de la rivière Kwinageese nous ne devrions pas considérer ces nombres comme étant une échappée totale à la rivière Kwinageese car le frayage pourrait prendre place dans le ruisseau Shanalope situé en aval du site de comptage. Il est aussi possible qu'une deuxième impulsion de saumons coho prit place après la fin du projet. Les données de l'échappée des saumons rouge sont complètes car la période d'études comprenait leur migration complète.

L'échappée adulte exacte et l'information dérivée du programme de marquage et de recapture sur la rivière Kwinageese vont permettre aux gestionnaires d'estimer l'échappée globale du saumon et les taux de récolte ainsi que les taux de survie des œufs d'alevins lorsque combinés avec les estimés hydroacoustiques à l'automne. Les données à l'exécution supplémentaires assisteront les gestionnaires à gérer les pêches au saumon rouge de la rivière Nass afin de protéger les stocks faibles.

INTRODUCTION

Included in the fisheries component of the Nisga'a Final Agreement was a commitment by all parties to conduct studies over a five-year period to address critical issues in the management of Nass salmon and annual accounting of Nisga'a salmon harvests (NFA 2000). Upper Nass River chinook and coho stocks were identified as priority stocks of concern and uncertainties regarding the escapement of these species in this area needed to be addressed. To this end, Nisga'a Fisheries Program staff proposed to develop new strategies and techniques to improve the accuracy and precision of escapement estimates for these stocks.

The need for an upper Nass indicator system for chinook and coho salmon was also identified by fisheries managers as a requirement to improve the ability to manage fisheries targeting these stocks for both conservation and economic benefit. It was proposed that an upper Nass indicator system be identified for intensive study of smolt production, survivals, exploitation and adult escapement. The Kwinageese River was selected as the best candidate to develop such a program.

Salmon that spawn in the upper Nass Area (above New Aiyansh) are subjected to an intense program of marking and recapture using fishwheels in the Nass River to derive in-season estimates of total run size for several species of salmon (Alexander et al. 2002). However, that approach does not allow for quantifying individual stocks (e.g., abundance of chinook salmon that spawn in the Kwinageese River). Carcass surveys that enumerate tagged and untagged fish in select watersheds have typically been performed to develop post-spawning estimates of escapement for aggregate upper Nass stocks. These carcass surveys however are limited in that they still do not quantify individual stocks and obtaining an adequate sample size is highly dependant on water conditions at the time of peak post spawning die off.

In 2000 the possibility of using video equipment to enumerate salmon on the Kwinageese River was explored by Nisga'a Fisheries and led to a pilot study being conducted in 2001 where digital video equipment was deployed and a partial weir constructed (Demarchi and Miller 2002). Results from this study indicated that, using a weir combined with video counting technology, it is feasible to obtain a complete census of individual stocks in the Kwinageese River as well as a large mark rate sample for upper Nass stocks.

The use of time-lapse video to collect accurate and affordable adult salmon escapement data is not new. A time-lapse video system was used to record the migration of Pacific salmon through a viewing window at Tumwater Dam on the Wenatchee River, Washington, from 1989 through 1991 (Hatch et al. 1994). In 1993, the Alaska Department of Fish and Game, Commercial Fisheries Division adapted the video camera technology used in the Columbia River Dam counting rooms for use at the existing Chignik River Weir in Alaska. This video system replaced live counts, and was conducted from structures mounted above the weir, with a camera mounted underwater. This provided count data during periods of turbid water conditions (Michael Daigneault, American Fisheries Society conference, Oct. 2002). In 1997, researchers in Idaho operated an analog time-lapse video system utilizing an under water camera in a video view box and a weir on both the Secesh River and Lake Creek to enumerate chinook salmon returning to those rivers (Faurot and Kucera 2003). The weir and video system on Lake Creek is

still in operation at the present time (Dave Faurot, Nez Perce Tribe, pers. comm.). In 1999, researchers in Alaska deployed a stand-alone video system that would enumerate salmon escapement in a remote setting (Otis and Dickson 2000). That system used time-lapse, analog video cassette recorders (VCR) combined with overhead and underwater cameras to record salmon passage in Delight Creek, this video system was unmanned and a weir was not used. In 2002, an underwater digital video system was used at Kincolith River, BC to enumerate chinook, pink and chum salmon passing through a weir, the video system also allowed for collection of adipose clip data for hatchery chinook without handling fish (Baxter et al. 2005).

Computer technology used to record video or edit analog tape is reasonably new. One such computerized editing system (used on some Columbia River Dams specifically for counting fish and described in Hatch et al. (1998)) uses a digital video motion detection algorithm which detects pixel changes of a defined magnitude in a portion of each video frame. Most recently, advances in the security and computer industries have led to dedicated digital video recorders (DVR's) which record to large and /or multiple computer hard drives (up to 150 gigabyte each) for extended record times and support for multiple cameras (up to 16). Because the recording media (hard disk) is non-linear, video can be retrieved at any point in time very quickly. In addition to recording in traditional time-lapse mode, DVR's can utilize video motion detection algorithms with adjustments for such variables as sensitivity, size of object, direction of motion, and target area in the field of view. A single camera detecting motion can queue other cameras to record, or multiple cameras can be configured to record independently. Other useful features found in DVR's as it applies to fisheries research include; duplex operation (record new video and playback pre-recorded video simultaneously), pre-motion recording (using a buffer), scheduled recording and audible video loss alarms.

GOALS AND OBJECTIVES

This study had two goals: (1) to enumerate adult chinook, sockeye and coho salmon in the Kwinageese River, and (2) to determine mark rates of these species from tags applied at the lower Nass fishwheels.

To meet these goals, the overall study had three primary objectives:

1. Deploy a digital video fish-counting system that is economical and efficient to operate and that yields accurate in-season information on numbers of salmon returning to spawn.
2. Obtain video images of sufficient quality to provide an annual census of chinook, sockeye and coho salmon escapement in the Kwinageese River.
3. Obtain video images of sufficient quality to determine mark rates of chinook, sockeye and coho salmon in the Kwinageese River.

STUDY AREA

The Kwinageese River in northwest British Columbia is a major tributary to the Nass River (Figure 1). The system is fed by several large lakes including Kwinageese Lake, Bonnie Lake and Fred Wright Lake (Figure 2). It is primarily driven by snowmelt in the spring and summer, and rainfall in the autumn. The Kwinageese watershed is approximately 52,000 ha with

a main channel length of over 40 km (Thomas and Gordon 1991). From its headwaters in the alpine, it flows southwest to Fred Wright Lake. A falls impassable to fish exists approximately 8.1 km upstream of Fred Wright Lake (Nass et al. 1993) or 41 km upstream of the Nass confluence. The outflow from Fred Wright Lake redirects the Kwinageese River in a northerly direction 2.7 km to Halfway Lake, it then continues north for another 25.9 km to its confluence with the Nass River. The Kwinageese River supports many species of salmonids including chinook (*Oncorhynchus tshawytscha*), sockeye (*O. nerka*), coho (*O. kisutch*), rainbow/steelhead (*O. mykiss*) and Dolly Varden (*Salvelinus malma*). Non-salmonid species within the watershed include mountain whitefish (*Prosopium williamsoni*), longnose dace (*Rhinichthys cataractae*), shiners (family *Cyprinidae*) and sculpins (family *Cottidae*).

The study site was located 18.5 km upstream of the Nass River confluence (Figure 1) at the West Kwinageese logging road bridge (position N 56° 03.35, W 128° 45.70) and was accessed via the Kwinageese Forest Service Road. The site is below chinook and sockeye spawning grounds however coho and chinook are known to spawn in Shanalope Creek, which is downstream of the study site (Koski et al. 1996a). A counting site below Shanalope Creek was not selected due to the higher gradient in that area and access limitations. Substrate at the chosen site consists predominately of large cobble and boulder and gradient is approximately 1.5%. Discharge calculations conducted at Kwinageese River in 2002 as part of a separate study showed an approximate discharge range of between 3 m^3/s and 79 m^3/s (Baxter 2003).

Radio tagging studies conducted in 1992 and 1993 (Koski et al. 1996a, b) showed that the major chinook spawning areas occur from Halfway Lake to 2.5 km downstream and from Halfway Lake to 1.5 km upstream, with minor spawning occurring in Shanalope Creek. Major sockeye spawning occurs from Fred Wright Lake to the falls barrier on the upper Kwinageese River and in lower Bonnie Creek. Adult coho spawner data could not be found but it is likely they spawn throughout the accessible habitat of the watershed.

METHODS

PHYSICAL OBSERVATIONS

Water temperature and level were recorded daily. Water velocity at the weir was only recorded at low flow and again at peak water flow. An electronic water gauge at the site also recorded water temperature, water level and air temperature (Baxter 2003). Daily water level was recorded in the morning from a staff gauge on the right bank of the river approximately 20 m upstream of the weir. The staff gauge was mounted to an inverted culvert, which supported and enclosed the electronic water gauge. Daily water temperature was collected in the morning using an alcohol-filled thermometer. Water velocity measurements at the weir were measured using a custom designed flow meter (J. Termuende, Edutech Technologies Corp. Gibsons Landing, BC).

ADULT WEIR

A uniquely designed weir was constructed at the Kwinageese River site to address specific site concerns relating to water velocity, volume and debris load. The weir was designed so it could be installed during early to mid July during a period of moderate to high water flows but on the descending limb of the hydrograph. To accomplish this a modified floating weir design was chosen utilizing a track and trolley deployment system combined with an inflatable bladder and planer (resistance) boards to keep the downstream end of the weir afloat and well above the water surface.

The base of the weir was a custom designed steel I-beam type track (Photos 1 & 2) which functioned as a sill rail and was secured to the river bottom in early May under low winter flows. The track, made of 3-m lengths, was bolted together on shore to a length of 15 m. Steel bars, 1.2-m long, were bolted perpendicular to the track every 1.5 m to help stabilize it and keep it flat to the bottom. The track was then dragged into place such that it was perpendicular to the river flow (Photo 3) and anchored with Duckbill[tm] anchors driven 1 m into the substrate and evenly spaced every 1.5 m. The track covered 15 m of the approximately 20-m bank width at the site.

Trolleys were designed to attach the weir panels to the track and roll along it such that panel attachment could be made next to shore in shallow slow moving water and then rolled out into the faster, deeper water. The trolleys were a custom built modified I-beam type trolley, each one being 30 cm long by 11.4 cm wide. They contained four 2.5 cm by 2.5 cm rollers which rolled along the upstream side of the I-beam track and two 2.5 cm by 10 cm rollers which rolled across the face (downstream side) of the I-beam to provide lateral stability (Photo 2). Two types of roller material were utilized, UHMW (ultra high molecular weight) plastic and polyurethane plastic, this was done to assess the performance of each material for this application. Trolleys were slipped onto the track from one end, the weir panel then attached to it using a 1.2 cm (½ inch) bolt through a bracket on the trolley and fitted loosely through an eyebolt attached to the panel. This arrangement allowed the panel to hinge up and down on the trolley.

Weir panel frames were each 3 m long by 1.5 m wide and made of 3.8 cm square aluminum tubing which were drilled to fit 1.9 cm (¾ inch) PVC schedule 40 pipe. The PVC pipe was passed through the aluminum frame for the length of the panel, end caps were cemented on which secured the pipe within the frame and made them air tight. Two eyebolts were attached to the bottom of each panel to secure them to the trolleys.

A 45 cm (18-inch) diameter inflatable air bladder, typically used for oil spill containment, was used to support six of the weir panels (9 linear meters) nearest the right bank (Photo 4). The air bladder allowed the weir to easily be lowered and raised from shore if required to remove debris or for safety during flood events. It was secured under and near the top end of the weir panels using 3 mm diameter cables and small shackles spaced every 30 cm. The air bladder was inflated through a 5 cm Monsun valve using an industrial leaf blower. Three panels (4.5 linear meters) on the left bank were supported by planer boards, these consisted of 1.2 m x 1.5 m sheets of plywood reinforced with aluminum and held at a 30 degree angle to the panel using cable attachments. The remaining 5 m of river at the ends of the weir were blocked to fish passage with fixed vertical weir panels (Photo 4).

An overhead cable was installed approximately 1.5 m over the downstream edge of the weir and anchored to trees on both banks. This cable was used to hold the ends of the weir panels above water during weir installation and as a back up to support the weir during high flows (Photo 5) or in the event the air bladder was damaged or failed.

VIDEO SYSTEM

Viewing Box

A viewing box was secured in the thalweg of the river 11 m from the right bank between two sections of the weir using Duckbill[tm] anchors. Fish were allowed to pass freely through the 1.2-m wide view box, 24 hours per day. The view box served several purposes; it helped control lighting conditions, provided a contrast background, kept fish within 1.2 m of the camera lens and provided a secure mount for underwater cameras and lights. The box consisted of a rectangular aluminum frame measuring 1.2 m wide, 1.2 m high and 2.1 m long, it was covered on the sides and top with plywood painted white on the inside (Photo 6). The plywood sides mounted in channels on the frame allowing easy removal for cleaning and maintenance. Underwater cameras were mounted with custom made brackets to a 3.8 cm square aluminum bar affixed to the bottom of the right hand plywood side such that the camera hung below the bottom edge of the plywood and viewed the left side of upstream migrating fish (Photo 7). A 15 cm wide plexi-glass window running the length of the view box was fixed in front of the cameras to prevent fish from swimming against or between cameras.

Cameras

Five different underwater NTSC (National Standards Television Committee) video cameras were used in this study in order to assess the merits and quality of each. Lenses of a focal length from 2.9 mm to 4.3 mm were used. Two of the cameras, one monochrome and one colour, were made by Integrated Aqua Systems in North Vancouver, BC and rated to a depth of 30 m. Two cameras, one monochrome and one colour, distributed by Micro Video in Bobcaygeon, Ont. incorporated built in LED (Light Emitting Diode) lights and were also rated to 30 m. One colour camera made by Extreme CCTV in Burnaby, BC was depth rated to only 0.9 m.

Lights

Lights, operating on 12-volt DC power, were fixed underwater inside the view box. Various combinations and positions of lighting were used throughout the season in attempt to provide even lighting of the video chamber. Lights used included small 8-watt florescent tubes, a 20-watt halogen pond light, a 35-watt halogen (automotive) floodlight, and LED lights built into cameras. A photo sensing switch mounted on top of the video viewing box automatically turned lights on at dusk and off at dawn.

Video Recording

A Silent Witness DVMS 1600 digital video recorder was the central part of the video system and had the following features, which made it an invaluable tool for this application:

- Non-linear recording media, allowing user to quickly start review at any point in time.
- Full duplex operation, records and plays back video simultaneously.
- Motion detection recording and time-lapse recording, which can operate simultaneously and independently.
- Multi screen view of all active cameras for live and recorded video.
- Recording of up to 14 days on one 120-gigabyte hard drive at high resolution (more if resolution and frame rate reduced).
- Up to sixteen-camera capability.

Video was recorded 24 hours per day onto 120-gigabyte computer hard drives. The recorder was generally set up to record from four cameras, the first camera (camera 1) was located at the downstream end of the video box and recorded in time-lapse mode at 3 frames per second (fps) 24 hours per day. A second camera, (camera 2) just upstream of the first was configured for video motion detection. If motion exceeding the minimum thresholds was detected then an alarm trigger prompted recording from cameras 1, 2 and a third camera (camera 3) located upstream of the second camera. With this arrangement, a fish travelling upstream would trigger recording on all three cameras as it entered the field of view of camera 2, although it would often only be seen on cameras 2 and 3 if it continued upstream. A fish travelling downstream would also trigger recording on all cameras as it entered the field of view of camera 2 but would only be seen on cameras 2 and 1 if it continued downstream (Figure 2). This configuration was particularly useful for viewing fish that may be travelling at a high rate of speed and only be captured in one or two video frames if using a single camera or for fish that entered the view box but then turned around and exited in the same direction from which they came. A fourth camera was installed for site security; it was not part of the study but recorded independently to the same recorder using separate motion detection settings. All camera views, live or recorded, could be viewed on the monitor simultaneously (quad screen) or independently for a larger image size. Additionally, a separate monitor was connected to the recorder so that live video could be displayed on one monitor and pre-recorded video played back on the other (Photo 8). Video recorded by motion detection consisted of short video clips of a user defined length and frame rate. Clips were kept short at 5 to 10 seconds each and had a high frame rate of 10 to 15 fps, this provided very fluid and clear video images (Photos 9-12) while consuming a minimum of hard drive space.

Recording in both time-lapse mode and motion detection mode can be achieved using only one camera. However, multiple cameras provided two independent camera systems for recording fish, this created a backup in the event one camera malfunctioned or had its field of view blocked by debris near the lens. This configuration also provided multiple views of individual fish or groups of fish, which aided in determining species and mark status.

Video recorded in time-lapse mode from camera 1 was used daily as a quality control check to ensure that motion detection was operating properly and not missing any fish, in cases

where fish were missed, only the time-lapse video was used for counts until such time it was determined the motion detection was operating at 100%. Reasons for motion detection missing fish were generally related to poor lighting conditions.

Power

The entire system was powered from a bank of six 6-volt deep cycle industrial "golf cart" batteries wired in both series and parallel to provide 12-volt DC power. Cameras and lights ran directly from 12-volt while power for the digital recorder was converted to 120-volt AC by a 300-watt inverter. Batteries were primarily charged during the day with a gasoline generator while crew was reviewing video. A hydroelectric generator was also used to charge batteries but could not provide enough power to run the system. Solar power was attempted but not utilized because mature tree cover at the site prevented direct sunlight in any one location for a sufficient period of the day.

VIDEO COUNTS

Fish counts were generally kept daily. Crew reviewed video on site using a 27 inch television monitor and the digital video recorder, which continued to record while review was being conducted. Data were collected for each hour using hand counters and transcribing to a daily data sheet. Data recorded included number of jacks by species, number of untagged fish by species, number of tagged fish by species and number of fish that tag status could not be certain by species. For tagged sockeye the tag colour was recorded and for tagged chinook the tag number was recorded if readable. For steelhead, data were collected on tag status as well as if an adipose punch was present (2002 fishwheel mark). Tag information was recorded in order to provide additional mark rate data for the Nisga'a Fisheries Fishwheel Program to determine escapement estimates for upper Nass salmon stocks. Data on resident fish (non-anadromous) were not collected since they moved frequently through the video chamber in both directions.

RESULTS

PHYSICAL OBSERVATIONS

Water temperatures during the chinook and sockeye migration at the Kwinageese River ranged from a maximum of 19 °C in late August to a minimum of 6.5 °C in mid-October at the end of the run (Figure 4, Table A-1). Water temperatures during the coho and steelhead migration ranged from a maximum of 19 °C in late August to a minimum of 7 °C during the first week of October.

During the period that the weir was operational, water level at the gauge ranged from 0.18 m to 0.91 m with an average level of 0.42 m (Figure 4, Table A-1). Water velocity at the weir, measured in the thalweg during the monitored period ranged from a minimum of 0.8 m/s on 21 August to a maximum of 2.0 m/s on 23 September. Velocity was only measured at extreme low flow and again at extreme high flow. As part of a separate study, a preliminary discharge curve was developed for the Kwinageese River (Baxter 2003). Using this curve,

discharge was calculated, and ranged from approximately 3 m^3/s to 79 m^3/s during the study period.

ADULT WEIR

The track and trolley system for weir deployment performed well, the track did not scour beneath nor did it become buried or plugged with substrate. Sand and small gravel did accumulate on the downstream side of the track in an eddy but was easily cleared away before installing the trolleys and weir. Some binding did occur when small gravel was pinched between a protruding bolt head on the trolley and a bolt head joining adjacent sections of the track, however this was not unduly problematic and can be avoided in the future with modification of the trolleys. The trolleys made with the UHMW plastic rollers performed much better than those with the softer polyurethane rollers. A single weir panel connected to the rail was pushed back and forth across the river using the two different trolleys; the ones with the UHMW plastic were much easier to push across the track. With three panels joined together and using polyurethane rollers, rolling resistance was great enough to require the assistance of a cable puller to pull the panels out into the river.

The aluminum-PVC weir panels were very robust and handled high water flows, debris and human loads without any damage or noticeable deformation. The inflatable bladder supported the end of the weir well above water until velocities reached approximately 1.5 m/s. At this velocity, water piled up on the upstream side and poured over the top, leaving the ends of the weir just above the surface. Ropes were attached to the panels and the overhead cable to lift and support the end of the weir well above the water when this occurred (Photo 5). The three weir panels located near the left bank, which were held up with resistance boards, performed very well at both high and low water and did not require any adjustments or maintenance throughout the season.

VIDEO SYSTEM

Recording

The Silent Witness DVMS 1600 performed very well in all modes of operation with only one malfunction during the season. Review of video recorded from motion detection was generally very efficient. False triggering did occur, caused from drifting debris or direct sunlight, but was not overly problematic. When several fish passed together over an extended period the motion detection was very quick to reset and trigger again with very few frames lost. At times resident bull trout would move into the video view box for extended periods to feed and for cover. This presented the problem of having the motion detection constantly triggered generating 6 to 10 video clips per minute. When this occurred reviewers resorted to viewing the time-lapse video from camera 1 as this was found to be more efficient.

The weir and video system operated from 17 July to 17 October, with only a few short down times primarily caused by human error (Table 1). On two occasions video data were lost due to equipment malfunction and in one case the recorder malfunctioned shortly after a hard drive change resulting in a 3-hour video loss. In another incident, the photo switch for the lights

failed resulting in a 2-hour loss of night time video. Both events occurred during a period of minimal fish movement and were corrected quickly by on site crew.

Cameras

Several different monochrome and colour cameras were used over the duration of this study; all were NTSC video cameras and rated to be submersible. One colour camera, model EX10, made by Extreme CCTV was rated to a depth of 1 m. However this camera leaked when submerged to this depth for an extended period, it had excellent video quality but turned out to be inappropriate for underwater use.

Two cameras distributed by Micro Video were used, one monochrome and one colour. The monochrome camera had six built in LED infrared lights surrounding the lens. Overall the camera performed very well, however, the infrared lights were ineffective because infrared light is absorbed very quickly in water. The colour camera had six white LED lights surrounding the lens. The camera itself performed very well and the lights greatly aided in night time viewing. However they were not powerful enough themselves to fully illuminate the 1.2 m depth of field. Both of the Micro Video cameras were somewhat fragile and required great care in handling and, due to their built in lights, both cameras caused a light reflection in the plexiglass viewing box window which required that large cutouts be made in the window.

Two cameras, one monochrome and one colour, made by Integrated Aqua Systems (IAS) for the marine aquaculture industry were also used in this study. These were the most robust of all the cameras. The monochrome camera performed very well especially in low light conditions. The colour camera, however, was very sensitive to electrical noise caused by charging the main battery bank and from the inverter used to power the DVR. This was the only camera with electrical noise problems. After unsuccessful attempts to filter out this electrical noise its use was discontinued.

Three different lens focal lengths were tested during this study; 2.9 mm, 3.4 mm and 4.3 mm. Within the confines of the video-viewing box, the wide-angle 2.9 mm lens was found to be most appropriate. This allowed the camera to be very close to the fish while still providing a very wide field of view. This lens also has the added benefit of being able to collect more light, thus requiring less illumination at night. Some distortion of the picture was noticed with this 2.9 mm "fisheye" lens. However, this did not present any problems.

Lights

Several different lighting configurations were used over the duration of the study in an effort to maximize light conditions at night by eliminating bright spots and shadows. All lights operated from 12-volt DC power, as it would be unsafe to operate 120-volt AC power over or in the river. Attempts were made to keep the power requirements for lights to a minimum in order to maximize battery life and eliminate the need to run a generator at night.

Initially a single 35-watt halogen automotive type floodlight was positioned in the video-viewing box above the surface of the water. This produced a single bright spot of light

underwater with a lot of moving shadows caused from surface refraction on the moving water. The halogen floodlight was then sealed with silicone and mounted underwater. While this eliminated the moving shadows it still had a primary bright spot, similar to a flashlight, with darker surrounding areas. Next, several 8-watt fluorescent tubes were silicone sealed and mounted underwater above and below the camera's field of view. These were effective in providing a more uniform light and a great improvement over the halogen floodlight. However, they were not powerful enough to adequately illuminate the full 1.2 m depth of field. A 20-watt underwater pond light, used for ornamental ponds, was then tested. This provided a spotlight effect but less so than the 35-watt halogen. When used in combination with the fluorescent tubes the pond light proved to be very effective when carefully positioned. Adjustments to light positions were made throughout the season; it was found that lights could not be mounted within the camera's field of view as this caused the auto iris in the camera to adjust for the brighter light which effectively made the rest of the picture darker. This effect was also noticed when there was any bright spot in the picture. The auto iris, adjusting for the bright spot of light, caused the remainder of the video picture to become darker.

VIDEO COUNTS

Viewing

Length of time required to review video was highly variable depending on fish passage rates and type of video being reviewed. In general, during periods of moderate fish passage the time-lapse video could be reviewed at a rate of 10 to 15 minutes per one-hour count period. If no fish were present, review time for a one-hour recording was approximately seven minutes. Motion detection video could be reviewed at an approximate average rate of three minutes per one-hour period. If no fish passage occurred during a one-hour period and false detections were few, the review time was less than one minute per hour of video. Water turbidity did not affect review time because turbidity was never excessive, even during high water events when turbidity increased. Although attempts were made to count jacks, fish could not be accurately sized using video. Thus, jack counts are considered minimums and adult counts likely include some jacks.

Chinook

A total of 1,893 adult chinook were counted through the weir via video review from 17 July to 13 October (Table 2). Of these 114 were tagged, 76 were of unknown tag status and five were identified as jacks (Table 3, Table B-1). Unknown tag status occurred when the tag area (left operculum) could not be clearly observed due to other fish obscuring the view or when the tag area was outside the camera field of view which sometimes occurred when chinook were very close to the camera. If the left operculum was unobstructed, tags were easily identified (Photo 9). Peak movement of chinook past the weir occurred on 2 August with 199 chinook observed (Figure 5, Table B-1). Total observed chinook should be considered a minimum escapement to the Kwinageese River since the chinook run was already underway at project start up. Based on the daily count pattern it is roughly estimated that 11 to 21% (200 to 400) of the chinook passed the counting site before the counting system was operational.

Sockeye

A total of 5,891 adult sockeye were counted through the weir via video review from 18 July to 30 September (Table 2). Of these, 86 were tagged, 88 were of unknown tag status, and two were identified as jacks (Table 3, Table B-2). Unknown tag status occurred when the tag area (behind dorsal fin) could not be clearly observed due to other fish obscuring the view or when the tag area was outside the camera field of view which sometimes occurred when sockeye were very close to the camera. Observers also recorded tag colours on sockeye (Photos 11-12) in order to collect run timing information for the Nass River fishwheel program. Peak movement of sockeye occurred on 2 August with 486 sockeye observed, a slightly smaller peak occurred 9 August with 434 sockeye observed (Figure 6, Table B-2). Total observed sockeye should be considered the total escapement to the Kwinageese River since the entire sockeye run was monitored and down times are not considered significant.

Coho

A total of 1,283 adult coho were counted through the weir via video review from 15 August to 16 October (Table 2). Of these, eight were tagged, 92 were of unknown tag status and seven were identified as jacks (Table 3, Table B-3). Unknown tag status occurred when the tag area (behind dorsal fin) could not be clearly observed due to other fish obscuring the view or when the tag area was outside the camera field of view, which sometimes occurred when coho were very close to the camera or swimming at the top edge of the field of view. Peak movement of coho occurred on 15 September when 94 coho were observed with a smaller peak occurring 28 September when 49 coho were observed (Figure 7, Table B-3). Total observed coho should be considered a minimum escapement to the Kwinageese River since significant spawning habitat is available in Shanalope Creek, which is downstream of the counting site. It is also possible that a second run of coho entered the Kwinageese after the October 17 shutdown date.

Steelhead

A total of 267 steelhead were counted through the weir via video review from 30 August to 17 October (Table 2). Of these, eight were adipose punched only (2002 fishwheel mark), three were tagged (tagged previous to 2002 or ocean tagged), 251 were unmarked and five steelhead were of unknown mark status (Table 3, Table B-4). Unknown mark status occurred when the mark area (behind dorsal fin or adipose fin) could not be clearly observed due to other fish obscuring the view or when the tag area was outside the camera field of view which sometimes occurred when steelhead were very close to the camera or swimming at the top edge of the field of view. Peak movement of steelhead occurred on 22 September with 22 steelhead observed (Figure 8, Table B-4). Total observed steelhead should not be considered the total escapement to the Kwinageese River since the steelhead run was still underway when escapement monitoring ceased.

DIEL MOVEMENTS

Chinook

Chinook migration past the Kwinageese River counting site occurred both day and night but with the vast majority of movement occurring during daylight hours. Only 12.3% of the total chinook migration occurred between the dark hours of 22:00 and 04:00. Peak movements occurred in the early morning hours between 05:00 and 07:00, which, in these two hours accounted for 19.4% of the total chinook migration (Table 4, Figure 9). The remaining chinook movement was distributed fairly evenly throughout the day.

Sockeye, Coho, Steelhead

Sockeye, coho and steelhead also migrated past the Kwinageese River counting site during both night and day, however movements directly related to a dark or light photo period were less prevalent than chinook. Sockeye migration at night (22:00 to 04:00) accounted for 28.1% of the total migration (Table 4, Figure 9). This is not low considering this 6-hour period accounts for 25% of a 24-hour day. Similar to, but earlier than chinook, peak sockeye movements occurred in the early morning hours between 04:00 and 06:00, which accounted for 19.5% of the total migration. Sockeye migration was lowest during mid-day, from 12:00 to 15:00 with only 3.5% passage during this time. Coho migration at night accounted for 31.9% of the total migration, coho showed a preference for travelling during evening, night and morning hours. Only 32.4% of the coho migrated past the Kwinageese counting facility during the 12-hour period from 08:00 to 20:00. Steelhead migration at night accounted for 37.1% of the total migration. As with coho, steelhead also showed a preference for travelling during evening, night and morning hours. Only 27.3% of the steelhead migrated past the Kwinageese counting facility during the 12-hour period from 08:00 to 20:00.

SOCKEYE TRAVEL TIMES

Travel times for sockeye from the lower Nass fishwheels to the Kwinageese weir were calculated based on tag releases of different tag colour groups and the subsequent observation of these coloured tags at the Kwinageese weir (Table 5, Table C-1). Travel times were calculated by first determining the weighted mean tag date for each tag colour group. Using the weighted mean tag date, the travel time for each individual coloured tag observed was calculated. From this, the average travel time for each colour group was determined (Figure 12). The overall mean travel time for sockeye is the average of all colour groups.

The overall average time for tagged sockeye to reach the weir was 30.9 days (n=85; Table 5). The maximum time for a tag colour group to reach the weir was 34.3 days for yellow tags (n=8) and the minimum time for a tag colour group to reach the weir was 26.0 days for brown tags (n=6). The maximum time for any one individual fish to reach the Kwinageese weir was 55 days and the minimum time for any one individual was 18 days (Table C-1). Based on the overall average travel time for sockeye to travel the 200 km distance from the lower Nass fishwheels to the Kwinageese weir the average rate of travel was 6.5 km/day. A higher

percentage of sockeye tagged at the fishwheels between 7 July and 20 July were recovered at the Kwinageese River weir (Table 5).

MARK RATES

To assist in upper Nass escapements in conjunction with the Nisga'a Fisheries fishwheel program, mark rate data were obtained for chinook, sockeye and coho salmon by observing the number of tags passing by the weir site. For the purpose of determining mark rates, hourly counts that contained a fish of unknown mark status were not included in the data used to calculate the mark rate. Mark rates for sockeye at the Kwinageese weir (1.5%, Figure 10a) were very similar to mark rates observed at the Meziadin fishway (1.8%, Figure 11a). Mark rates for chinook at the Kwinageese River weir (6.3%, Figure 10b) were also similar to observed mark rates at the Meziadin fishway (4.5%, Figure 11b). Coho mark rates observed at the Kwinageese weir (0.7%, Figure 10c) were much lower than what was observed at the Meziadin fishway (1.7%, Figure 11c).

DISCUSSION

OVERALL VIDEO PERFORMANCE

Using digital video technology to record fish passage at Kwinageese River proved to be an effective method for enumerating salmon escapement to this river and for determining mark rates for upper Nass salmon. The digital motion detection feature of the video recorder combined with our camera configuration and viewing box allowed crew to review fish passage very efficiently especially during periods of low fish passage. Digital motion detection does have its limitations however; lighting must be kept as uniform as possible with avoidance of direct sunlight. Lights for night time use must brightly and evenly illuminate the viewing area. A defined contrast must exist between the fish and the background. If dark shadows exist then fish can pass through these areas undetected. Entrained air in the water column must be kept to a minimum, as bubbles near the camera lens will cause false detections. Resident and migratory fish must be discouraged from holding or feeding within the camera field of view so as not to generate continuous video clips.

Settings for motion detection are a balance between missing fish and recording false detections. While some false detections are acceptable, missing fish are not. If false detections are too frequent, then the entire purpose of recording in motion detection mode is defeated, as viewing video becomes more labour intensive than viewing simple time-lapse video. At times motion detection could not be used. For example, in early August we observed that at night resident bull trout were utilizing the lights in the video chamber to feed on chinook smolts. This fish activity caused the motion detection to constantly trigger generating 6 to 10 video clips per minute. When this occurred reviewers resorted to viewing the time-lapse video from camera 1 as this was found to be more efficient.

Further improvements to our video viewing chamber to more closely control lighting conditions will make motion detection recording even more efficient. Additionally a video

viewing box that slightly increases the velocity of water travelling through it may help prevent fish from holding within the camera field of view.

With any fisheries project, cost is always an important consideration. The video system components used at Kwinageese River in 2002 are listed in Table D-1 and provide a relative cost breakdown by system component. Costs for video equipment depend on the goals of the study, which dictate the type of video equipment to be utilized. The most basic video system would consist of a time-lapse VCR, single monochrome camera and a light source, however, this type of system has many shortcomings and is very labour intensive to review video. Digital video recording, multiple cameras and video motion detection increases equipment costs and system complexity but provide higher quality video and greatly reduces the number of man-hours required to view video.

A video system utilizing only monochrome cameras will reduce the overall cost of the system and monochrome cameras perform better than colour in low light conditions. This reduces the amount of illumination, thus power required at night. Colour cameras are only required when attempting to determine tag colours on fish but are also very useful for assisting viewers with species identification when similar appearing species may be present at the same time.

Operational and weir costs are more site specific and depend on such factors as site remoteness, crew size, weir design and river width. In many cases existing weirs can reduce labour costs during periods of low fish passage by installing a digital video system.

DIEL MOVEMENTS

Observations of diurnal movements of chinook at Kwinageese River in 2002, where 12.3% of the chinook passage occurred between the dark hours of 22:00 to 04:00, are similar to those observed at Tumwater Dam on the Wenatchee River in Washington by Hatch et al. (1994). Using a time-lapse video recorder system, they monitored the migration of adult sockeye, chinook and steelhead at the fish-viewing window over a three-year period and found mean night (20:00 to 4:00) passage for chinook to be 13.56 percent (SD = 1.06%) of the daily passage. This study utilized very bright, white lights for night illumination, which could have affected fish behaviour at night. It is possible that on the Kwinageese River the white lights used to illuminate the video chamber at night caused some of the chinook to hold below the weir until early morning. This however, was not observed for the other species of salmon passing through the video chamber. Observations of diurnal movements at Kwinageese River contrast to what researchers in Idaho found at a similar video counting facility at Lake Creek where, in 2001, 37% of the net upstream movement occurred between 22:00 and 04:00 and from 1998 to 2000 42-82% of the net upstream movement occurred between these hours (Faurot and Kucera 2003). This study utilized red LED lighting to illuminate the video counting chamber, in part to eliminate possible fish avoidance of white light. White lights were used on the Kwinageese River in order to provide colour video information to aid in species identification and determine sockeye tag colours.

POPULATION ESTIMATES AND MARK RATES

A total of 5,891 adult sockeye were video counted through the weir during the 18 July to 30 September time period. This total included 86 sockeye that had been tagged at the Nass River fishwheels as part of the Nisga'a Fisheries fishwheel stock assessment program. Mark rates at the Kwinageese weir (1.5%) were very similar to mark rates observed at the Meziadin fishway (1.8%) and indicated that Kwinageese River sockeye mark rates provided a reliable secondary mark rate for Nass River sockeye. The counts of sockeye at the Kwinageese weir is considered be the total escapement to the Kwinageese system.

A total of 1,893 adult chinook were video counted through the weir during the 17 July to 13 October time period, and included 114 chinook that had been tagged at the Nass River fishwheels. This total should be considered a minimum escapement as the chinook run was already underway at project start up. Mark rates observed at the Kwinageese weir (6.3%) were slightly higher than that observed at the Meziadin fishway (4.5%) and could possibly be related to missing the earlier part of the run thus inflating the mark rate.

During the 15 August to 16 October time period a total of 1,283 adult coho were video counted at the Kwinageese weir. This total included eight coho that had been tagged at the Nass River fishwheels. This total should be considered a minimum as the fence was demobilized on 17 October and a late run of coho may have entered the system after shut down. Mark rates at the Kwinageese weir (0.7%) were significantly lower than that observed at the Meziadin fishway (1.7%) and may have been due to underestimating the amount of tags, as the entire run may not have been captured.

A total of 267 steelhead were video counted at the Kwinageese weir from 30 August to 17 October and is considered a minimum estimate of escapement. Of these, eight were adipose punched (Nass River fishwheel mark) and three were tagged with other identifying marks.

RECOMMENDATIONS

Given the success of the video enumeration in 2002, future studies at the Kwinageese River using a weir and video at the 2002 study site are recommended. Continued data collection at this site will provide fishery managers with much needed data on upper Nass salmon stocks. Specifically, the program would provide:

1. Escapement estimates of sockeye for the Kwinageese system, a weaker stock relative to Meziadin River which comprises an average of 75% of the total sockeye salmon escapement to the Nass River (Bocking et al. 2002);
2. Secondary mark rates to validate mark rates obtained at Meziadin for sockeye, chinook and coho;
3. Timing information for Kwinageese sockeye moving past the Nisga'a in-river fisheries; and
4. Escapement estimates of chinook and coho in the Kwinageese River.

The video system should start in early July and operate to mid October (or longer) in order to cover the complete duration of the chinook, sockeye and coho runs. Modifications should be made to the video-viewing box to make flow conditions within it undesirable to resident bull trout. These modifications should also include provisions to enhance lighting conditions, thus improving identification of sockeye tag colours and making motion detection more reliable. Modifications can also be made to the weir roller assemblies, which will allow them to pass through the small gravel that accumulates on the downstream side of the track.

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TABLES

Table 1. Video equipment down times at Kwinageese River counting weir in 2002.

Video Loss		Video Restart		Total Down Time	
Date	Time	Date	Time	(hrs)	Comments
17-Jul	22:00	18-Jul	5:00	7.00	Lights not setup
13-Aug	1:20	13-Aug	8:05	6.75	Human error
16-Aug	20:45	17-Aug	9:00	12.25	Human error
29-Aug	6:00	29-Aug	10:00	4.00	Power Loss
02-Sep	0:50	02-Sep	12:05	11.25	Power Loss
29-Sep	19:00	29-Sep	21:00	2.00	Photo switch failure
01-Oct	17:00	Oct-01	18:00	1.00	System maintenance
07-Oct	9:00	07-Oct	14:00	5.00	Hard drive full
08-Oct	8:00	08-Oct	12:00	4.00	Recorder failure
09-Oct	18:00	09-Oct	22:00	4.00	Leaf on main camera
11-Oct	5:00	11-Oct	7:00	2.00	Leaf on main camera
		Total for Season		59.25	

Table 2. Counts of adult chinook, sockeye, coho and steelhead by week at Kwinageese River in 2002.

Week Ending	Chinook	Sockeye	Coho	Steelhead
20-Jul [a]	146	13	0	0
27-Jul	317	180	0	0
3-Aug	410	1,436	0	0
10-Aug	445	1,879	0	0
17-Aug	133	599	4	0
24-Aug	255	1,013	35	0
31-Aug	139	365	122	1
7-Sep	29	74	67	3
14-Sep	9	251	220	6
21-Sep	8	65	410	33
28-Sep	1	11	181	73
5-Oct	0	5	143	72
12-Oct	0	0	84	51
19-Oct [a]	1	0	17	28
Total Adults	1,893	5,891	1,283	267

[a] denotes incomplete weeks

Table 3. Total counts of chinook, sockeye, coho and steelhead, Kwinageese River, 2002.

	Chinook	Sockeye	Coho	Steelhead
Adults Untagged	1,703	5,717	1,183	251
Adults Tagged	114	86	8	3
Adults Adipose Punched	N/A	N/A	N/A	8
Adults Unknown	76	88	92	5
Jacks	5	2	7	N/A
Total Adults	1,893	5,891	1,283	267

Table 4. Diel movements of chinook, sockeye, coho and steelhead passing through the Kwinageese River counting fence by hour in 2002.

	Chinook		Sockeye		Coho		Steelhead	
Time	# of fish	% of total	# of fish	% of total	# of fish	% of total	# of fish	% of total
00:00	25	1.3	257	4.4	80	6.2	12	4.5
01:00	24	1.3	255	4.3	68	5.3	16	6.0
02:00	40	2.1	276	4.7	57	4.4	14	5.2
03:00	49	2.6	327	5.5	70	5.4	24	9.0
04:00	86	4.5	527	8.9	52	4.0	22	8.2
05:00	224	11.8	627	10.6	50	3.9	14	5.2
06:00	145	7.6	322	5.5	116	9.0	20	7.5
07:00	96	5.1	252	4.3	53	4.1	16	6.0
08:00	107	5.6	234	4.0	25	1.9	4	1.5
09:00	99	5.2	153	2.6	17	1.3	4	1.5
10:00	75	4.0	165	2.8	17	1.3	8	3.0
11:00	113	6.0	113	1.9	34	2.6	3	1.1
12:00	76	4.0	48	0.8	29	2.2	8	3.0
13:00	100	5.3	79	1.3	40	3.1	7	2.6
14:00	93	4.9	83	1.4	59	4.6	9	3.4
15:00	90	4.7	126	2.1	57	4.4	5	1.9
16:00	78	4.1	261	4.4	49	3.8	4	1.5
17:00	89	4.7	220	3.7	34	2.6	7	2.6
18:00	70	3.7	236	4.0	27	2.1	0	0.0
19:00	34	1.8	226	3.8	30	2.3	14	5.2
20:00	40	2.1	243	4.1	95	7.4	10	3.7
21:00	50	2.6	324	5.5	94	7.3	13	4.9
22:00	66	3.5	311	5.3	66	5.1	16	6.0
23:00	29	1.5	227	3.9	71	5.5	17	6.4
Total	1,898 [a]	100	5,892 [a]	100.0	1,290 [a]	100.0	267	100.0
Movements by photo period								
Night [a]	233	12.3	1,653	28.1	412	31.9	99	37.1
Day	1,665	87.7	4,239	71.9	878	68.1	168	62.9

[a] Total net upstream counts, including jacks

[b] Night is defined by the period of darkness from 22:00 to 04:00

Table 5. Timing and abundance of tagged sockeye from the Nass River fishwheels to the Kwinageese River in 2002.

Tag Color	Tag Period	Weighted mean tag date	No. Released	Avg. Time to Weir (days)	No. counted at Weir	% Tagged to Weir
Forrest.Green	21-25 Jun	22-Jun	1,976	27.3	4	0.20
Yellow	26 Jun - 6 Jul	03-Jul	2,481	34.3	8	0.32
Blue	7-13 Jul	10-Jul	1,074	33.0	25	2.33
Pink	14-20 Jul	17-Jul	976	33.3	15	1.54
Brown	21-27 Jul	24-Jul	1,356	26.0	6	0.44
Florescent. Green	28 Jul - 1 Aug	30-Jul	782	30.0	3	0.38
White	2-17 Aug	08-Aug	1,105	32.5	4	0.36
Grey	18 Aug - 9 Sep	27-Aug	542		0	0.00
Unknown					6	
Unknown (brown?)					14	
	Total		10,292		85	0.83
			Mean	30.9		
			Max	34.3		
			Min	26.0		

FIGURES

Figure 1. Map of Nass River watershed showing the Kwinageese River and the location of Nisga'a Communities

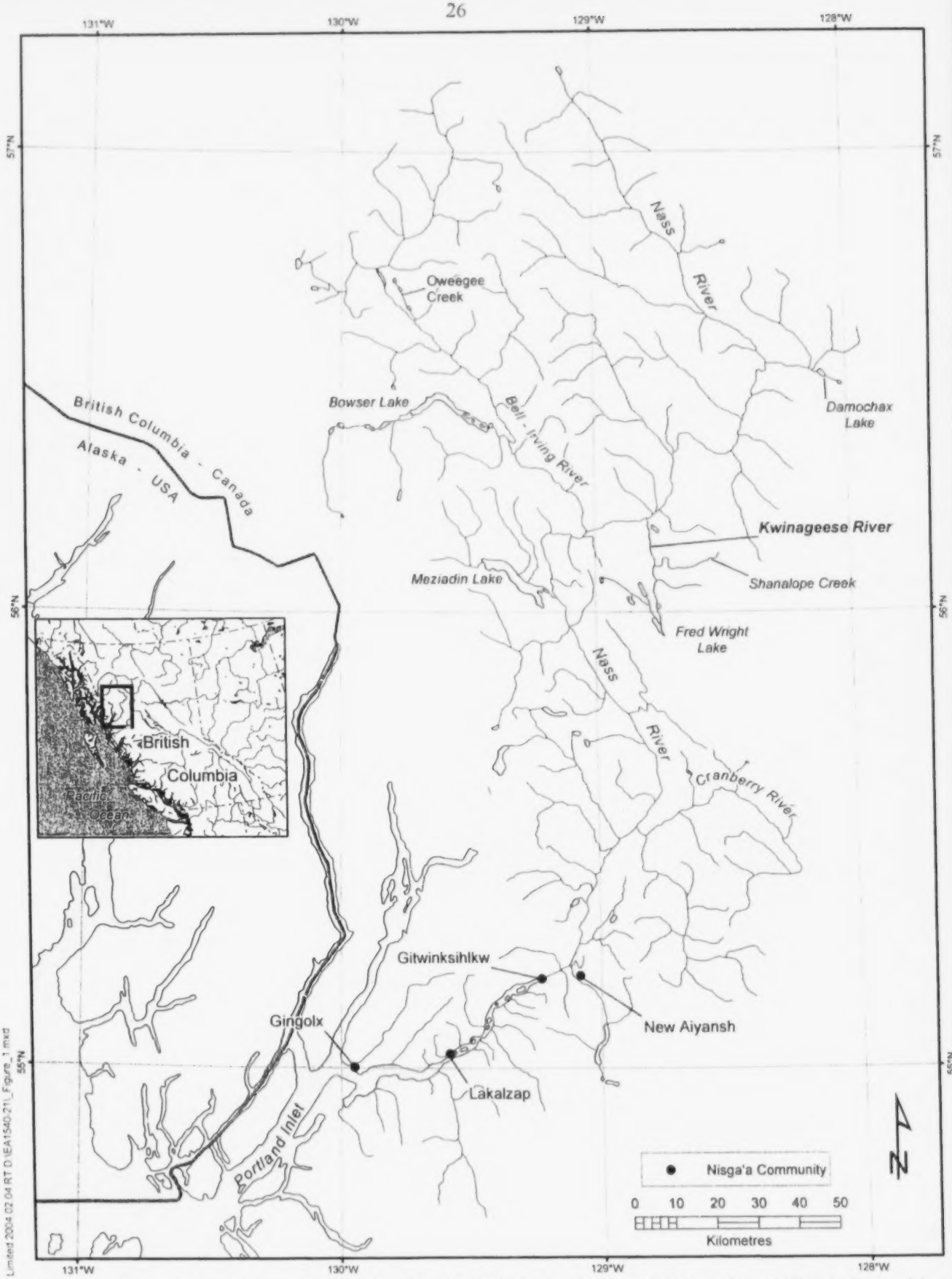

Figure 1. Map of Nass River watershed showing the Kwinageese River and the location of Nisga'a Comunities.

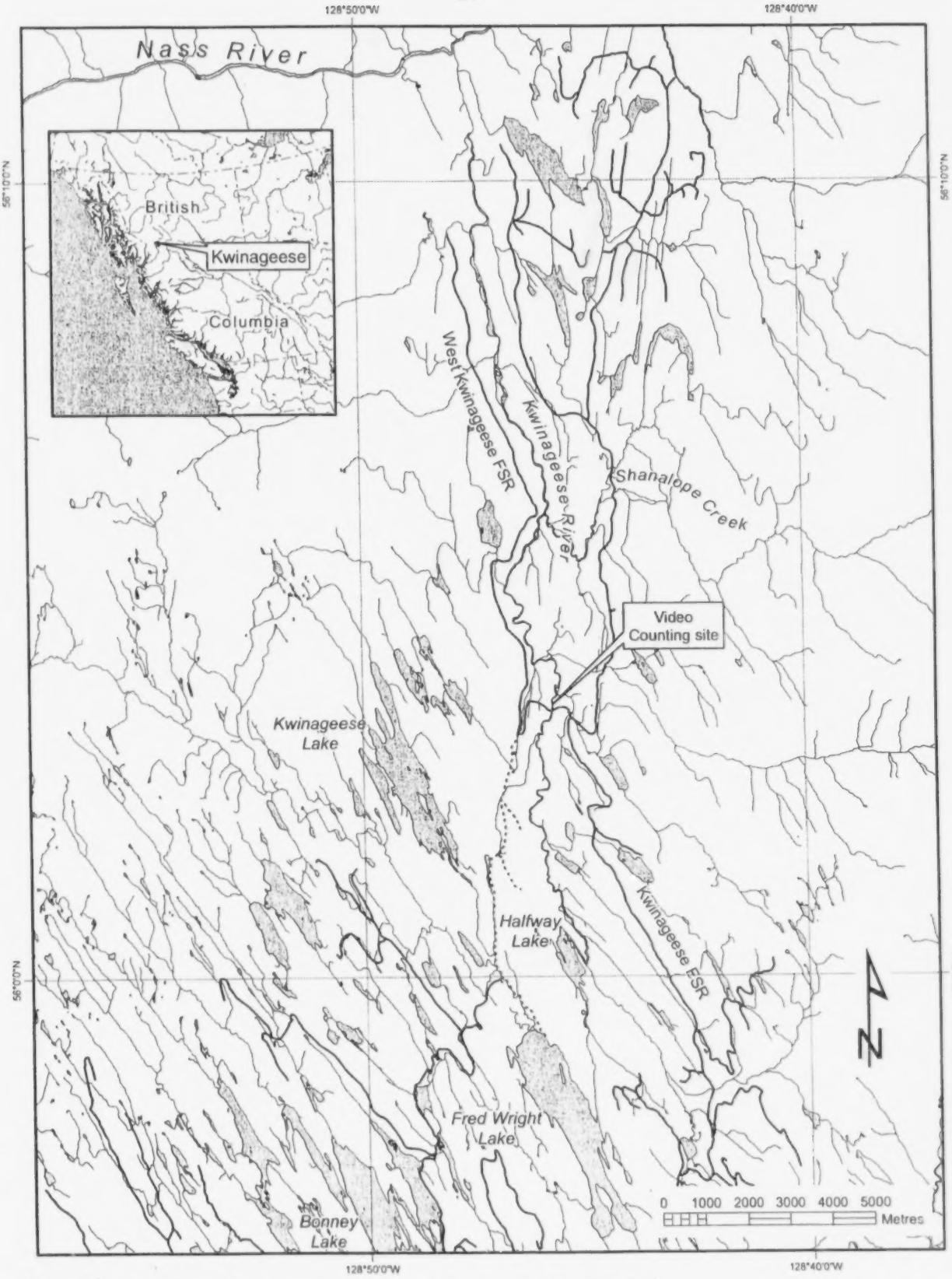

Figure 2. Location of Kwinageese video site in the upper Nass watershed.

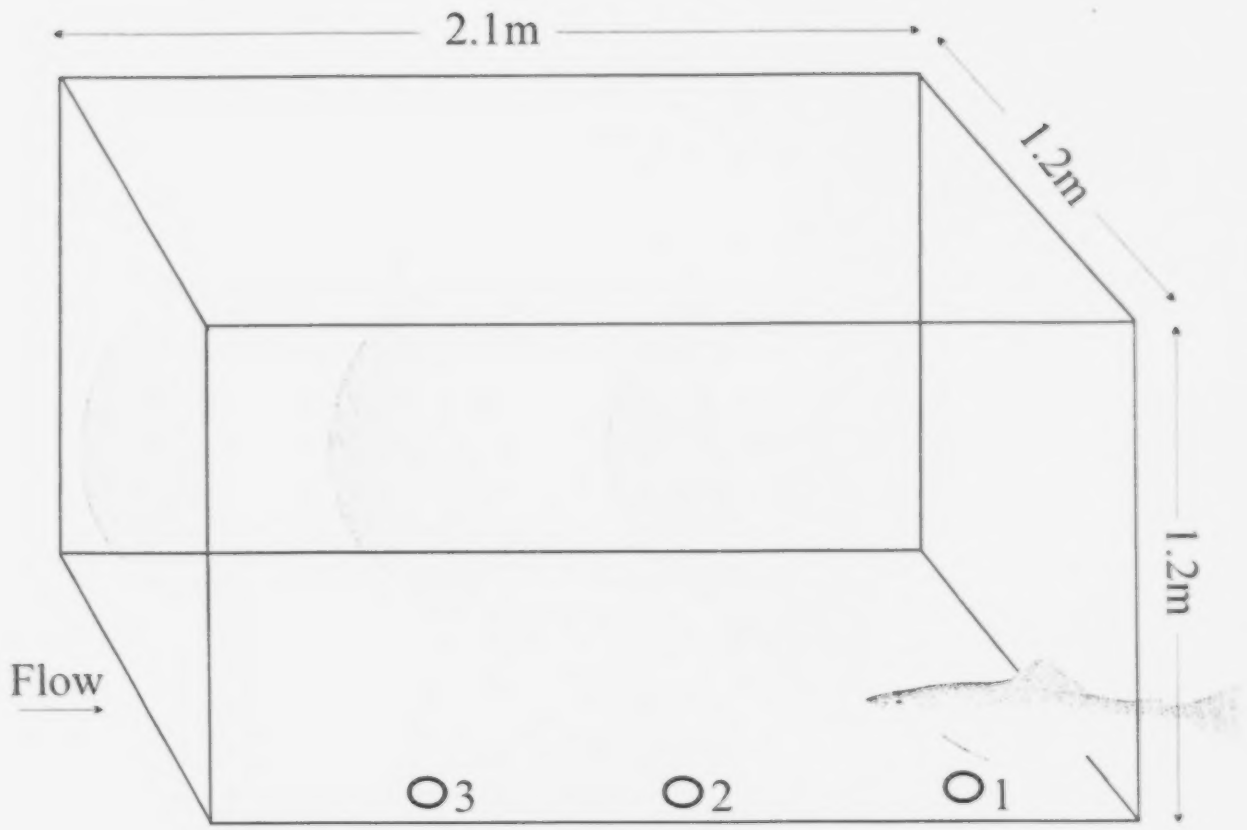

Figure 3. Camera configuration at Kwinageese River in 2002.

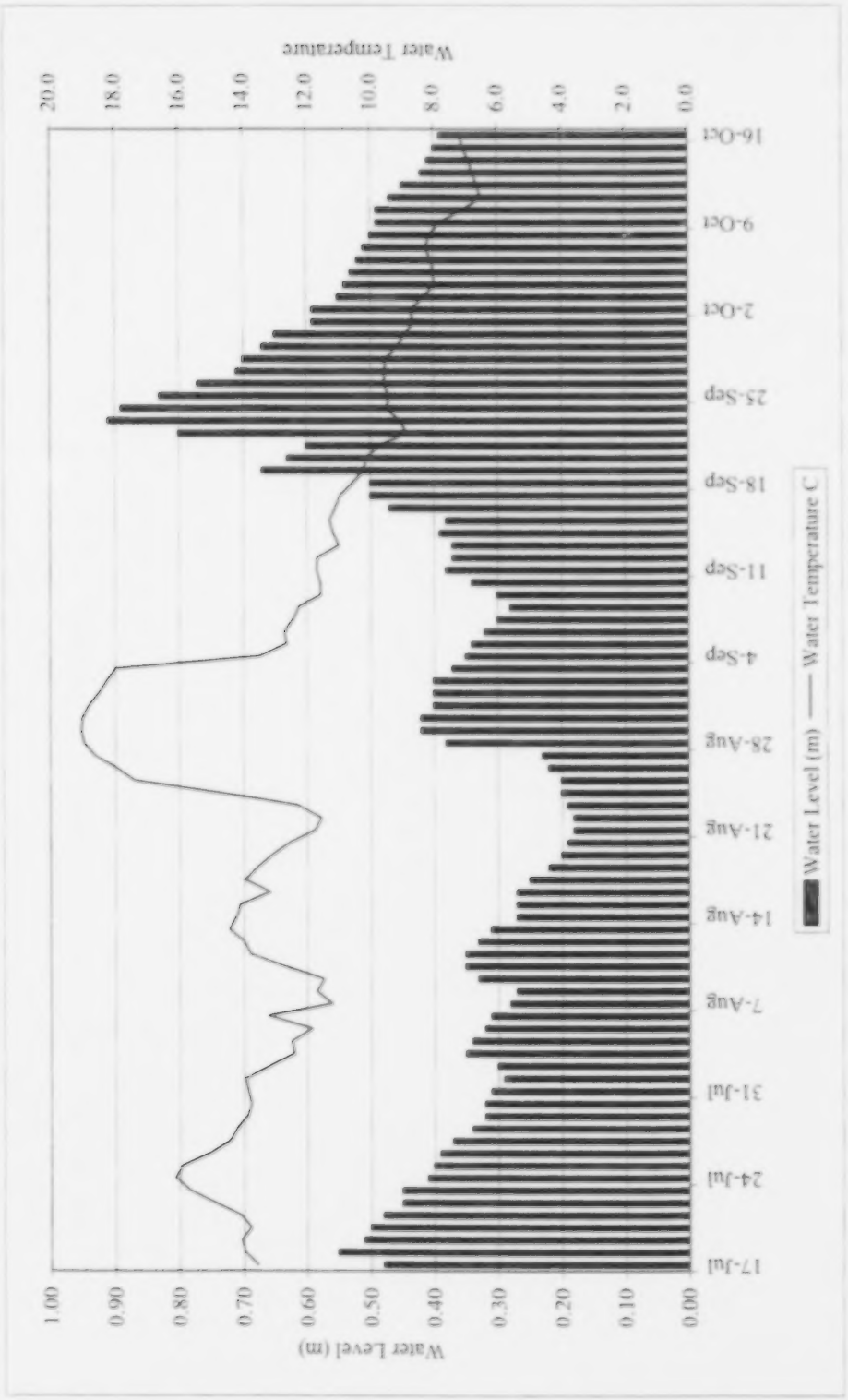

Figure 4. Water level and temperature at Kwinageese River, 2002

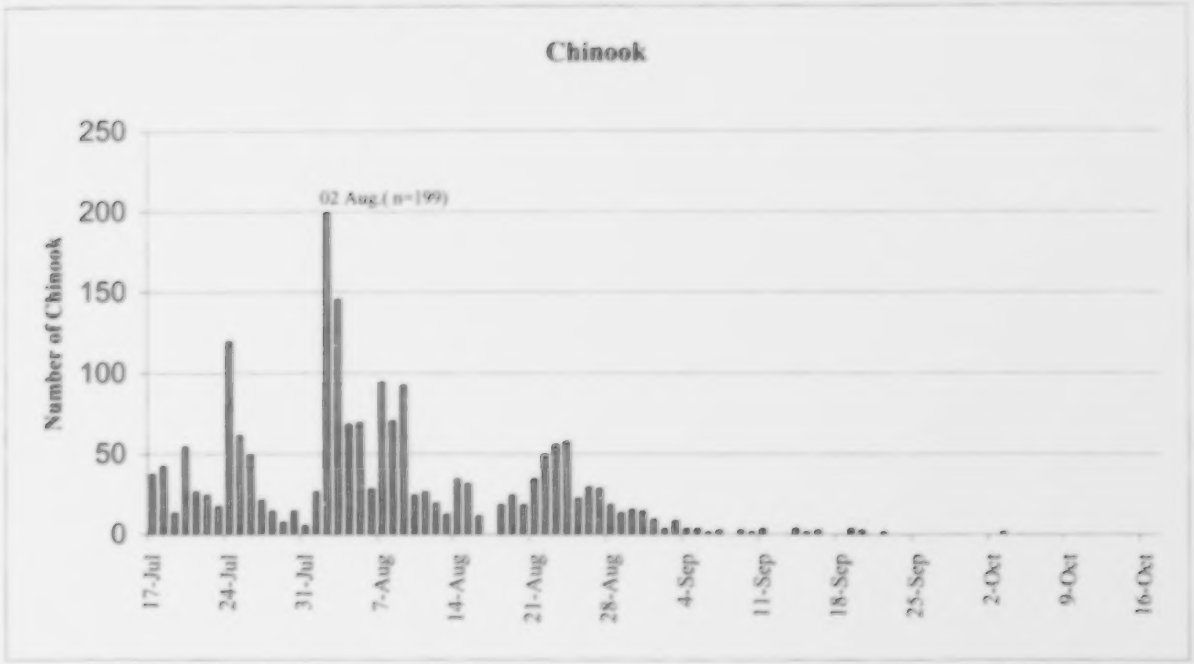

Figure 5. Daily net upstream counts of adult chinook through Kwinageese River counting fence, 2002.

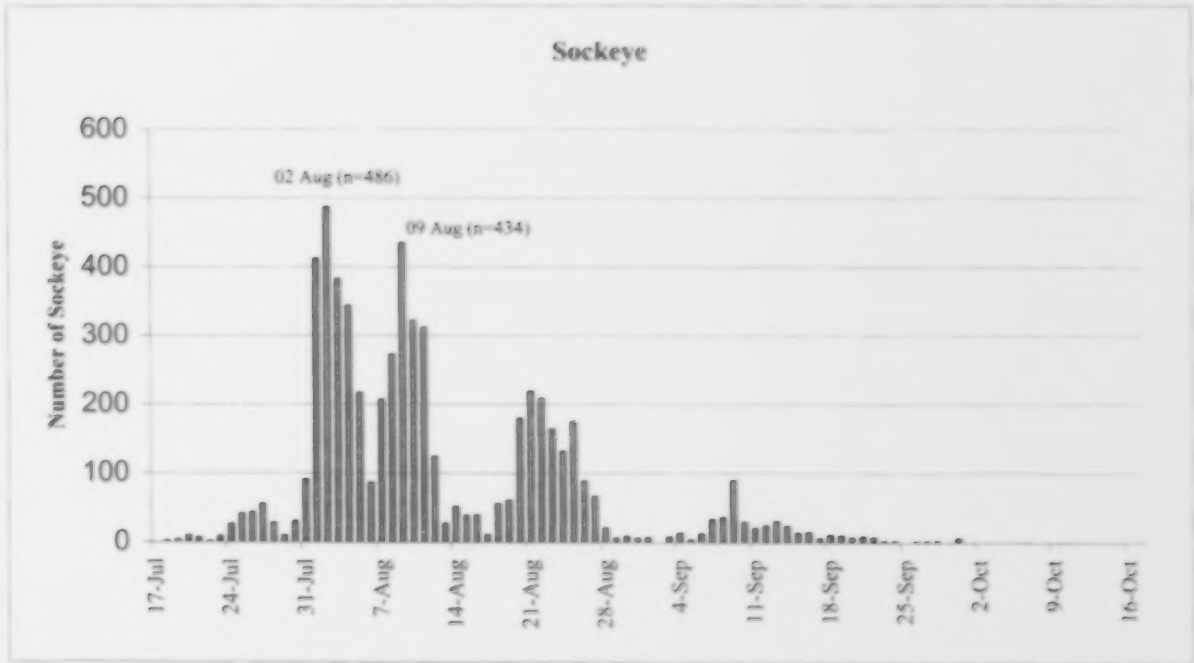

Figure 6. Daily net upstream counts of adult sockeye through Kwinageese River counting fence, 2002.

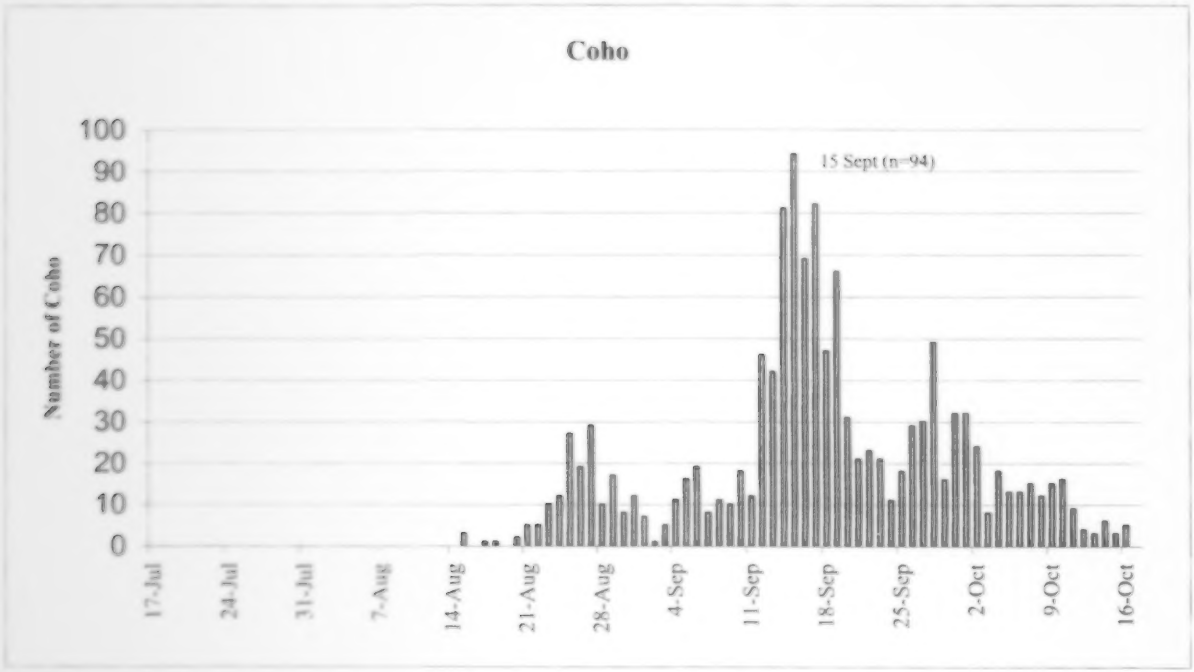

Figure 7. Daily net upstream counts of adult coho through Kwinageese River counting fence, 2002.

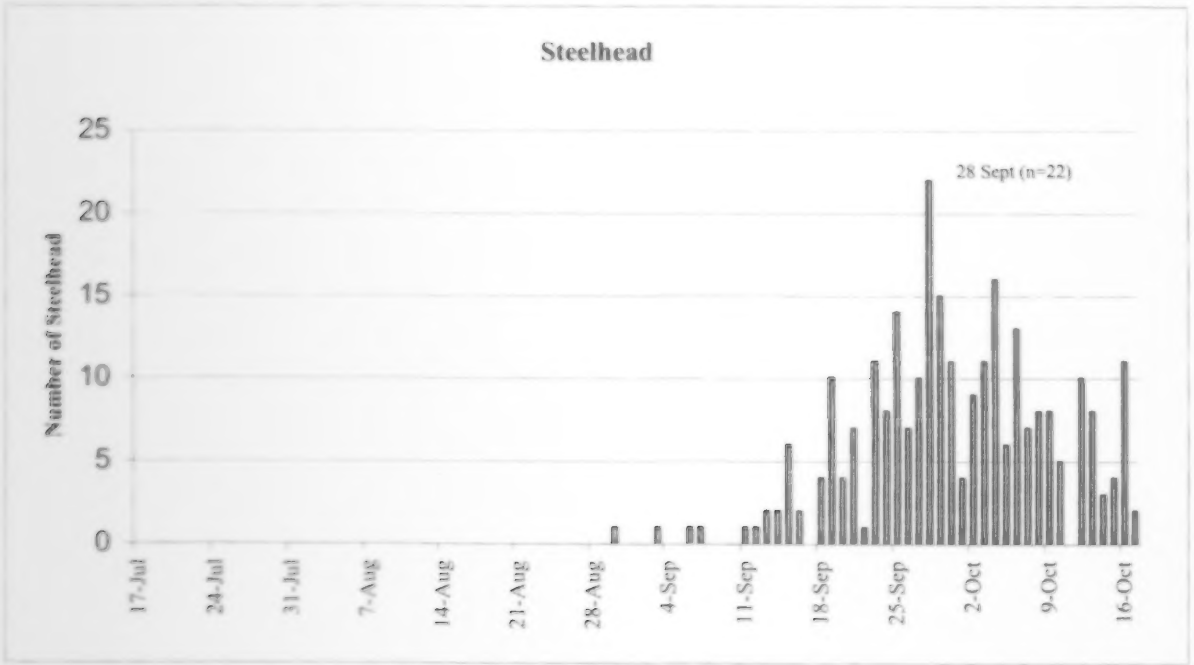

Figure 8. Daily net upstream counts of adult steelhead through Kwinageese River counting fence, 2002.

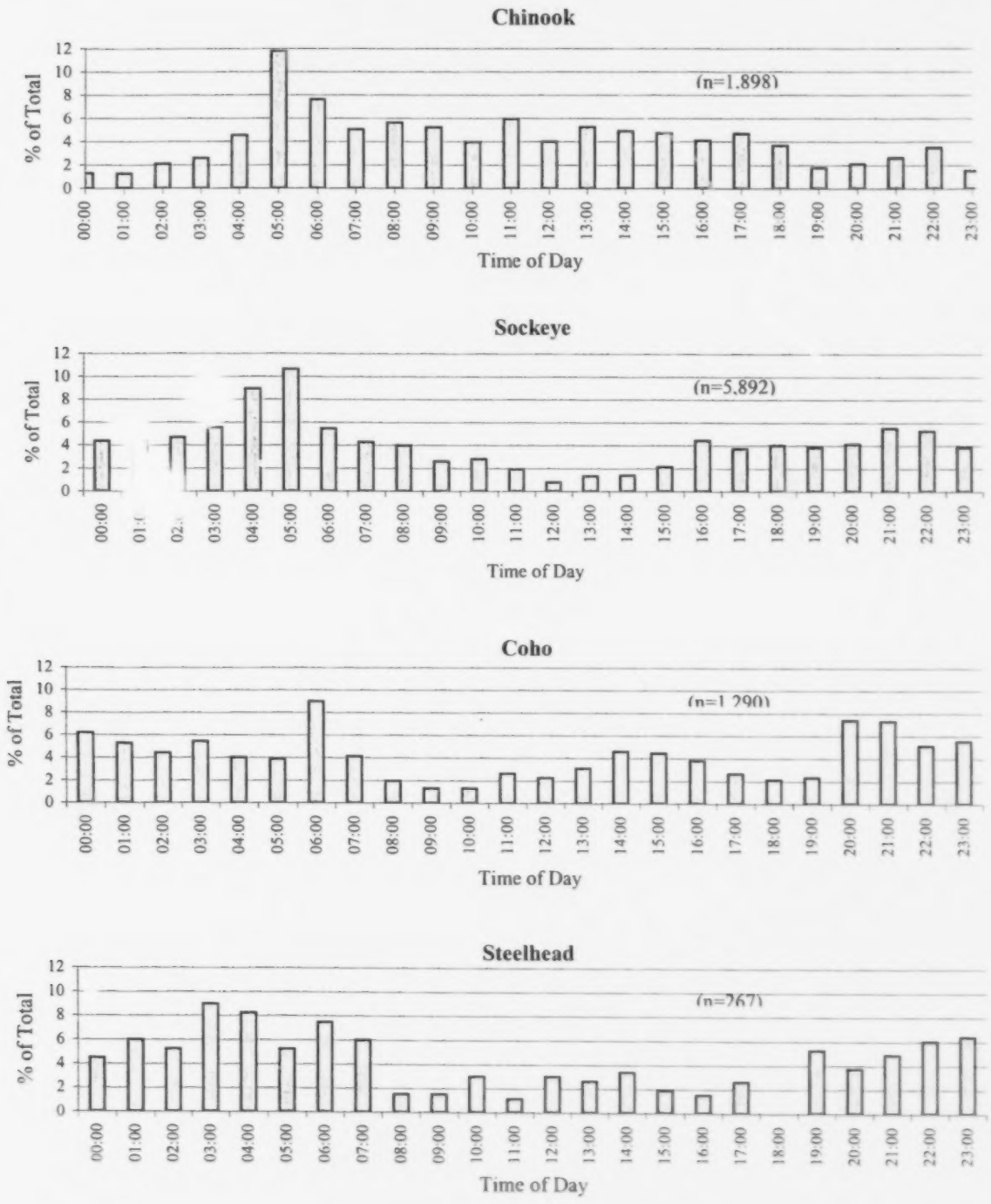

Figure 9. Diel timing of chinook, sockeye, coho and steelhead migration through the Kwinageese River video counting weir in 2002.

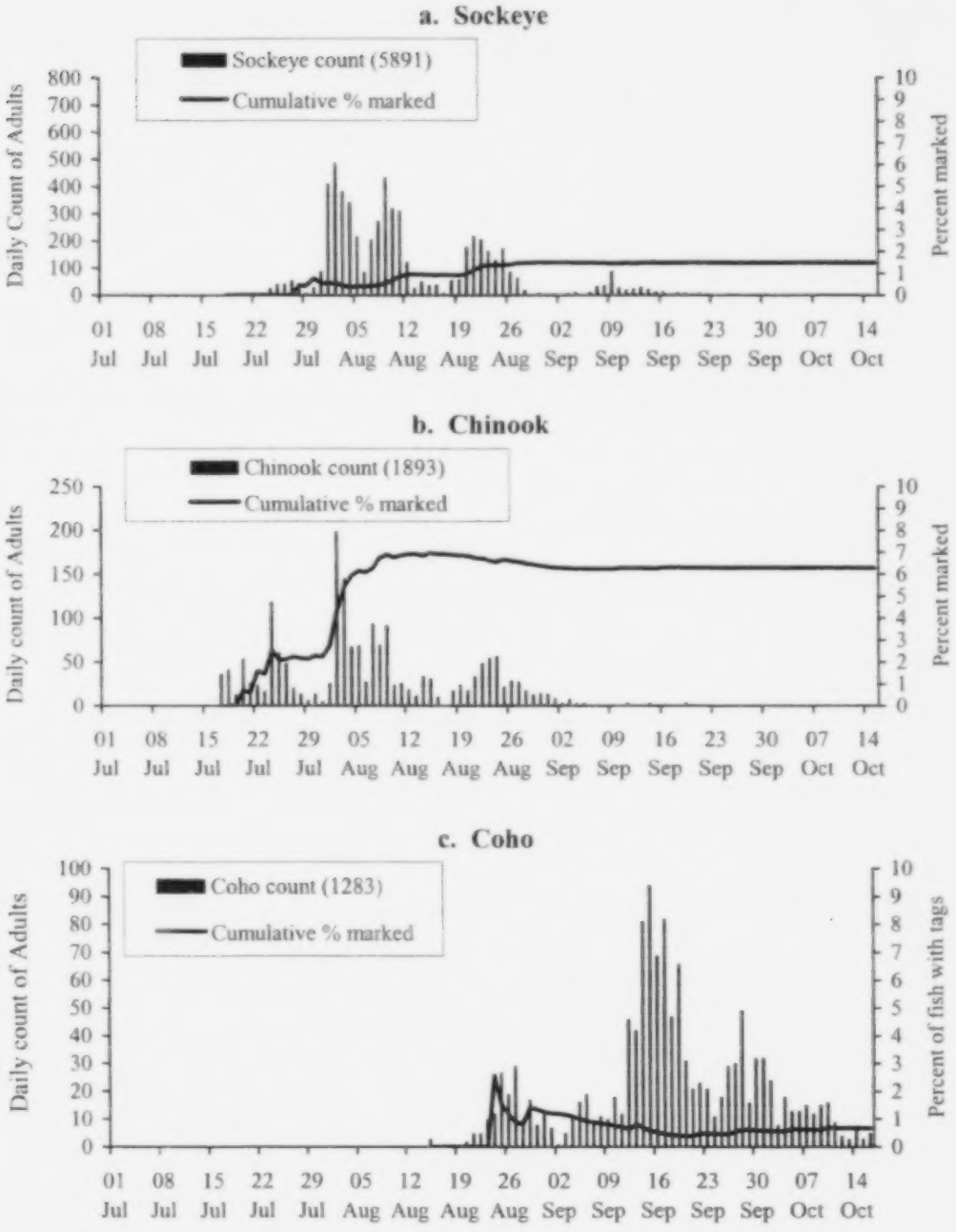

Figure 10. Daily counts and mark rate for sockeye, chinook and coho salmon passing through the Kwinageese weir, 17 July to 17 October 2002.

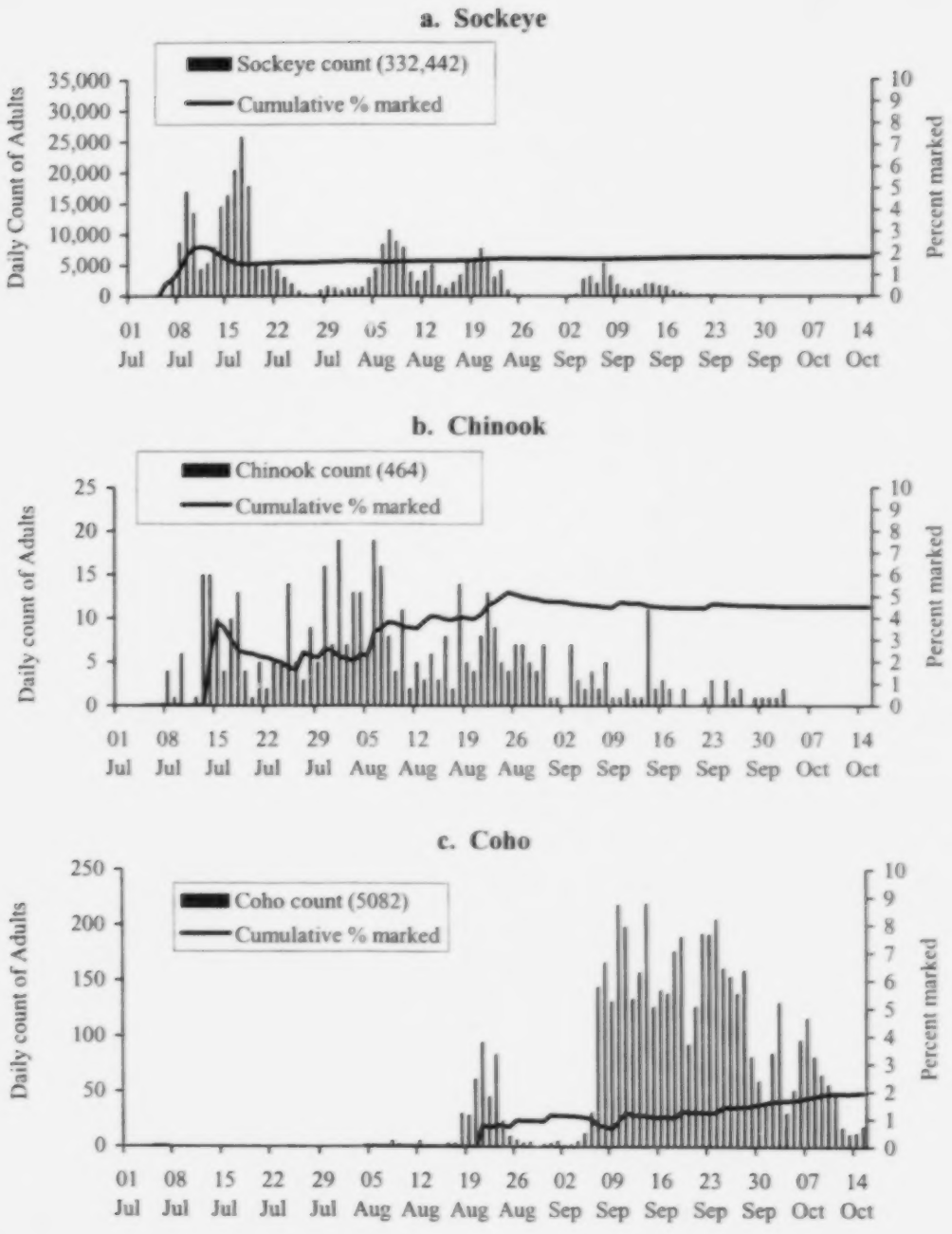

Figure 11. Daily counts and mark rate for sockeye, chinook and coho salmon passing through the Meziadin fishway, 1 July to 15 October 2002. Data from Alexander and Bocking, In Prep.

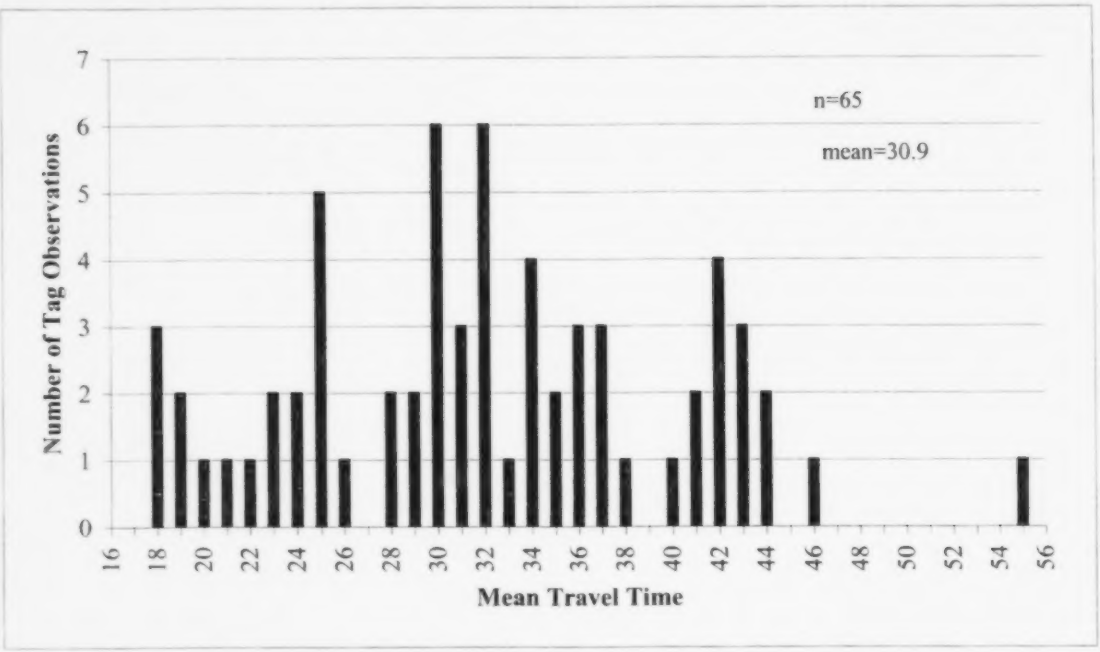

Figure 12. The distribution of mean travel times (days) to the Kwinageese River counting site for sockeye salmon tagged at the Nass River fishwheels, 2002

APPENDIX A

Physical data collected at the Kwinageese River Weir, 2002

Table A-1. Physical data collected at Kwinageese River, 2002.

Date	Water Level (m)	Water Temperature (° C)
17-Jul	0.48	13.6
18-Jul	0.55	14.0
19-Jul	0.51	14.1
20-Jul	0.50	13.8
21-Jul	0.48	14.1
22-Jul	0.45	14.9
23-Jul	0.45	15.7
24-Jul	0.41	16.1
25-Jul	0.40	15.9
26-Jul	0.39	15.1
27-Jul	0.37	14.4
28-Jul	0.34	14.2
29-Jul	0.32	13.9
30-Jul	0.32	13.8
31-Jul	0.31	13.9
1-Aug	0.29	14.0
2-Aug	0.30	13.2
3-Aug	0.35	12.4
4-Aug	0.34	12.5
5-Aug	0.32	11.8
6-Aug	0.31	13.2
7-Aug	0.28	11.2
8-Aug	0.27	11.7
9-Aug	0.33	11.5
10-Aug	0.35	12.7
11-Aug	0.35	13.8
12-Aug	0.33	14.0
13-Aug	0.31	14.4
14-Aug	0.27	14.2
15-Aug	0.27	14.1
16-Aug	0.27	13.2
17-Aug	0.25	13.9
18-Aug	0.22	13.6
19-Aug	0.20	13.1
20-Aug	0.19	12.5
21-Aug	0.18	11.7
22-Aug	0.18	11.5
23-Aug	0.19	12.3
24-Aug	0.20	14.7
25-Aug	0.20	17.4
26-Aug	0.22	18.0
27-Aug	0.23	18.6
28-Aug	0.38	19.0
29-Aug	0.42	19.0
30-Aug	0.42	19.0
31-Aug	0.40	18.8
1-Sep	0.40	18.5
2-Sep	0.40	18.2

Table A-1. Physical data collected at Kwinageese River, 2002.

Date	Water Level (m)	Water Temperature (° C)
3-Sep	0.37	18.0
4-Sep	0.35	13.5
5-Sep	0.34	12.6
6-Sep	0.32	12.7
7-Sep	0.30	12.4
8-Sep	0.28	12.2
9-Sep	0.30	11.5
10-Sep	0.34	11.6
11-Sep	0.38	11.7
12-Sep	0.37	11.7
13-Sep	0.37	11.0
14-Sep	0.39	11.2
15-Sep	0.38	11.3
16-Sep	0.47	11.1
17-Sep	0.50	10.9
18-Sep	0.50	10.5
19-Sep	0.67	10.2
20-Sep	0.63	10.1
21-Sep	0.60	9.7
22-Sep	0.80	8.8
23-Sep	0.91	9.0
24-Sep	0.89	9.5
25-Sep	0.83	9.4
26-Sep	0.77	9.6
27-Sep	0.71	9.5
28-Sep	0.70	9.5
29-Sep	0.67	9.2
30-Sep	0.65	8.9
1-Oct	0.59	8.6
2-Oct	0.59	8.7
3-Oct	0.55	8.3
4-Oct	0.54	8.0
5-Oct	0.53	8.0
6-Oct	0.52	8.1
7-Oct	0.51	8.3
8-Oct	0.50	8.1
9-Oct	0.49	7.8
10-Oct	0.49	7.1
11-Oct	0.47	6.5
12-Oct	0.45	6.6
13-Oct	0.42	6.8
14-Oct	0.41	6.9
15-Oct	0.40	7.1
16-Oct	0.39	7.1
Mean	0.42	12.22
Min	0.18	6.51
Max	0.91	19.04
Std Dev.	0.16	3.26

APPENDIX B

Daily counts at the Kwinageese River Counting Weir, 2002

Table B-1. Daily net upstream counts of chinook at Kwinageese River, 2002.

Date	Chinook Jacks	Chinook Untagged	Chinook Tagged	Chinook Unknown	Total Adults
17-Jul-02		37			37
18-Jul-02		40		2	42
19-Jul-02		13			13
20-Jul-02		53	1		54
21-Jul-02		22		4	26
22-Jul-02		22	2		24
23-Jul-02	1	16		1	17
24-Jul-02		108	5	6	119
25-Jul-02		61			61
26-Jul-02		45	1	3	49
27-Jul-02	1	20	1		21
28-Jul-02		14			14
29-Jul-02		7			7
30-Jul-02		13	1		14
31-Jul-02		5			5
01-Aug-02		20	3	3	26
02-Aug-02		171	16	12	199
03-Aug-02		119	15	11	145
04-Aug-02		58	8	2	68
05-Aug-02		58	6	5	69
06-Aug-02		25	1	2	28
07-Aug-02	1	77	7	10	94
08-Aug-02	1	51	9	10	70
09-Aug-02		82	8	2	92
10-Aug-02		24			24
11-Aug-02		23	3		26
12-Aug-02		15	2	2	19
13-Aug-02		11	1		12
14-Aug-02	1	33	1		34
15-Aug-02		27	4		31
16-Aug-02		11			11
17-Aug-02		0			0
18-Aug-02		17	1		18
19-Aug-02		23	1		24
20-Aug-02		16	1	1	18
21-Aug-02		33	1		34
22-Aug-02		46	3		49
23-Aug-02		53	2		55
24-Aug-02		54	3		57
25-Aug-02		19	3		22
26-Aug-02		28	1		29
27-Aug-02		27	1		28
28-Aug-02		18			18
29-Aug-02		13			13
30-Aug-02		15			15
31-Aug-02		14			14
01-Sep-02		9			9

Table B-1. Daily net upstream counts of chinook at Kwinageese River, 2002.

Date	Chinook Jacks	Chinook Untagged	Chinook Tagged	Chinook Unknown	Total Adults
02-Sep-02		3			3
03-Sep-02		8			8
04-Sep-02		3			3
05-Sep-02		3			3
06-Sep-02		1			1
07-Sep-02		2			2
08-Sep-02		0			0
09-Sep-02		2			2
10-Sep-02		0	1		1
11-Sep-02		3			3
12-Sep-02		0			0
13-Sep-02		0			0
14-Sep-02		3			3
15-Sep-02		1			1
16-Sep-02		1	1		2
17-Sep-02		0			0
18-Sep-02					0
19-Sep-02		3			3
20-Sep-02		2			2
21-Sep-02		0			0
22-Sep-02		1			1
23-Sep-02					0
24-Sep-02					0
25-Sep-02					0
26-Sep-02					0
27-Sep-02					0
28-Sep-02					0
29-Sep-02					0
30-Sep-02					0
01-Oct-02					0
02-Oct-02					0
03-Oct-02		1			1
04-Oct-02		-1 [a]			-1
05-Oct-02					0
06-Oct-02					0
07-Oct-02					0
08-Oct-02					0
09-Oct-02					0
10-Oct-02					0
11-Oct-02					0
12-Oct-02					0
13-Oct-02		1			1
Grand Total	5	1,703	114	76	1,893

[a] Denotes fish moving downstream.

Table B-2. Daily net upstream counts of sockeye at Kwinageese River, 2002.

Date	Sockeye Jacks	Sockeye Untagged	Sockeye Tagged	Sockeye Unknown	Total Adults
17-Jul-02					0
18-Jul-02		1			1
19-Jul-02		3			3
20-Jul-02		9			9
21-Jul-02		6			6
22-Jul-02		1			1
23-Jul-02		8			8
24-Jul-02		26			26
25-Jul-02		41			41
26-Jul-02		43			43
27-Jul-02		55			55
28-Jul-02		27	1		28
29-Jul-02		9			9
30-Jul-02		29	1		30
31-Jul-02		90			90
01-Aug-02		401	2	8	411
02-Aug-02		473	3	10	486
03-Aug-02		361		21	382
04-Aug-02		332		11	343
05-Aug-02		212	2	3	217
06-Aug-02		86			86
07-Aug-02		186	1	19	206
08-Aug-02		263	2	7	272
09-Aug-02		425	5	4	434
10-Aug-02		315	6		321
11-Aug-02		301	9	1	311
12-Aug-02		118	4	1	123
13-Aug-02		26	1		27
14-Aug-02		50		1	51
15-Aug-02		38			38
16-Aug-02		39			39
17-Aug-02		9	1		10
18-Aug-02		55			55
19-Aug-02		60			60
20-Aug-02		174	4	1	179
21-Aug-02		208	10		218
22-Aug-02		197	10		207
23-Aug-02		157	6		163
24-Aug-02		129	2		131
25-Aug-02		171	2		173
26-Aug-02		85	3		88
27-Aug-02		62	4		66
28-Aug-02		19	1		20
29-Aug-02	1	5			5
30-Aug-02		7	1		8
31-Aug-02		5			5
01-Sep-02		6			6

Table B-2. Daily net upstream counts of sockeye at Kwinageese River, 2002.

Date	Sockeye Jacks	Sockeye Untagged	Sockeye Tagged	Sockeye Unknown	Total Adults
02-Sep-02		0			0
03-Sep-02		7			7
04-Sep-02		13			13
05-Sep-02		3			3
06-Sep-02		12			12
07-Sep-02		33			33
08-Sep-02		36			36
09-Sep-02		89			89
10-Sep-02		28	1		29
11-Sep-02		19	1		20
12-Sep-02		24			24
13-Sep-02		29	1		30
14-Sep-02		22	1		23
15-Sep-02		13			13
16-Sep-02		14			14
17-Sep-02		5			5
18-Sep-02		10			10
19-Sep-02		8	1		9
20-Sep-02		6			6
21-Sep-02		7		1	8
22-Sep-02		6			6
23-Sep-02		1			1
24-Sep-02		1			1
25-Sep-02					0
26-Sep-02		1			1
27-Sep-02	1	1			1
28-Sep-02		1			1
29-Sep-02					0
30-Sep-02		5			5
Grand Total	2	5,717	86	88	5,891

Table B-3. Daily net upstream counts of coho at Kwinageese River, 2002.

Date	Coho Jacks	Coho Untagged	Coho Tagged	Coho Unknown	Total Adults
15-Aug-02		3			3
16-Aug-02					0
17-Aug-02		1			1
18-Aug-02		1			1
19-Aug-02					0
20-Aug-02		2			2
21-Aug-02		5			5
22-Aug-02		5			5
23-Aug-02		10			10
24-Aug-02		11	1		12
25-Aug-02		27			27
26-Aug-02		19			19
27-Aug-02		29			29
28-Aug-02	1	10			10
29-Aug-02		16	1		17
30-Aug-02		8			8
31-Aug-02		11		1	12
01-Sep-02		7			7
02-Sep-02		1			1
03-Sep-02		5			5
04-Sep-02	1	11			11
05-Sep-02		16			16
06-Sep-02		19			19
07-Sep-02		8			8
08-Sep-02		11			11
09-Sep-02		10			10
10-Sep-02		18			18
11-Sep-02		12			12
12-Sep-02		46			46
13-Sep-02		41	1		42
14-Sep-02		75		6	81
15-Sep-02		83		11	94
16-Sep-02		65		4	69
17-Sep-02		80		2	82
18-Sep-02		38		9	47
19-Sep-02	2	49		17	66
20-Sep-02		27		4	31
21-Sep-02		17		4	21
22-Sep-02		22	1		23
23-Sep-02		15		6	21
24-Sep-02		11			11
25-Sep-02	2	16		2	18
26-Sep-02		27		2	29
27-Sep-02		28	1	1	30
28-Sep-02		46	1	2	49
29-Sep-02		16			16
30-Sep-02	1	25		7	32
01-Oct-02		25		7	32

Table B-3. Daily net upstream counts of coho at Kwinageese River, 2002.

Date	Coho Jacks	Coho Untagged	Coho Tagged	Coho Unknown	Total Adults
02-Oct-02		21		3	24
03-Oct-02		8			8
04-Oct-02		17		1	18
05-Oct-02		12	1		13
06-Oct-02		13			13
07-Oct-02		15			15
08-Oct-02		12			12
09-Oct-02		14		1	15
10-Oct-02		14	1	1	16
11-Oct-02		9			9
12-Oct-02		4			4
13-Oct-02		3			3
14-Oct-02		6			6
15-Oct-02		3			3
16-Oct-02		4		1	5
17-Oct-02		0			0
Grand Total	7	1,183	8	92	1,283

Table B-4. Daily net upstream counts of steelhead at Kwinageese River, 2002.

Date	Steelhead Adult	Steelhead Tagged	Steelhead Ad Punched	Steelhead Unknown	Total Adults
30-Aug-02	1				1
31-Aug-02					0
01-Sep-02					0
02-Sep-02					0
03-Sep-02	1				1
04-Sep-02					0
05-Sep-02					0
06-Sep-02	1				1
07-Sep-02	1				1
08-Sep-02					0
09-Sep-02					0
10-Sep-02					0
11-Sep-02	1				1
12-Sep-02	1				1
13-Sep-02	2				2
14-Sep-02	2				2
15-Sep-02	5			1	6
16-Sep-02	1	1			2
17-Sep-02					0
18-Sep-02	4				4
19-Sep-02	8	1		1	10
20-Sep-02	4				4
21-Sep-02	7				7
22-Sep-02	1				1
23-Sep-02	10		1		11
24-Sep-02	8				8
25-Sep-02	14				14
26-Sep-02	7				7
27-Sep-02	10				10
28-Sep-02	19	1	1	1	22
29-Sep-02	14			1	15
30-Sep-02	11				11
01-Oct-02	4				4
02-Oct-02	9				9
03-Oct-02	11				11
04-Oct-02	15		1		16
05-Oct-02	6				6
06-Oct-02	13				13
07-Oct-02	6		1		7
08-Oct-02	8				8
09-Oct-02	8				8
10-Oct-02	3		2		5
11-Oct-02	0				0
12-Oct-02	10				10
13-Oct-02	7		1		8
14-Oct-02	3				3
15-Oct-02	4				4
16-Oct-02	10			1	11
17-Oct-02	1		1		2
Grand Total	251	3	8	5	267

APPENDIX C

Recovery data for sockeye tagged at Nass River fishwheels, 2002

Table C-1. Color observations and travel times for tagged sockeye from the Nass River fishwheels to Kwinageese River in 2002.

Tag Colors Observed at Kwinageese Weir			Minimum time to reach weir (days)	Weighted mean time to reach weir
Date	Time	Color		
28-Jul	4:24:46	Blue	15	18
30-Jul	4:44:35	Blue	17	20
01-Aug	21:07:58	Blue	19	22
01-Aug	4:00:15	Yellow	26	29
02-Aug	4:52:08	Blue	20	23
02-Aug	8:26:52	Yellow	27	30
02-Aug	22:55:11	Yellow	27	30
05-Aug	16:33:27	Yellow	30	33
07-Aug	21:02:07	Blue	25	28
08-Aug	21:36:49	Blue	26	29
08-Aug	4:16:43	Yellow	33	36
09-Aug	18:02:14	Blue	27	30
09-Aug	20:33:09	Blue	27	30
09-Aug	21:57:32	Blue	27	30
09-Aug	23:02:40	Blue	27	30
09-Aug	10:59:31	Yellow	34	37
10-Aug	1:55:57	Blue	28	31
10-Aug	10:17:50	Blue	28	31
10-Aug	18:48:05	Pink	21	24
10-Aug	19:48:23	Pink	21	24
10-Aug	1:09:18	U		
10-Aug	3:50:20	Yellow	35	38
11-Aug	1:30:16	Blue	29	32
11-Aug	3:55:35	Blue	29	32
11-Aug	5:02:42	Blue	29	32
11-Aug	5:24:40	Blue	29	32
11-Aug	22:48:54	Blue	29	32
11-Aug	20:56:20	Brown	15	18
11-Aug	6:03:04	Pink	22	25
11-Aug	8:30:18	Pink	22	25
11-Aug	10:24:47	Pink	22	25
12-Aug	3:30:54	Brown	16	19
12-Aug	17:03:09	Brown	16	19
12-Aug	17:50:50	Pink	23	26
12-Aug	17:47:54	U (brown?)		
13-Aug	22:04:47	Yellow	38	41
17-Aug	23:15:27	U (brown?)		
20-Aug	1:57:24	Blue	38	41
20-Aug	4:48:06	FL Green	19	21
20-Aug	1:49:38	Pink	31	34
20-Aug	19:24:37	U (brown?)		
21-Aug	6:25:40	Blue	39	42
21-Aug	7:24:16	Blue	39	42
21-Aug	1:45:34	Pink	32	35
21-Aug	23:15:48	Pink	32	35

Table C-1. Color observations and travel times for tagged sockeye from the Nass River fishwheels to Kwinageese River in 2002.

Tag Colors Observed at Kwinageese Weir			Minimum time to reach weir (days)	Weighted mean time to reach weir
Date	Time	Color		
21-Aug	6:05:25	U		
21-Aug	7:12:31	U		
21-Aug	4:09:16	U (brown?)		
21-Aug	6:51:18	U (brown?)		
21-Aug	7:36:52	U (brown?)		
21-Aug	7:57:08	U (brown?)		
22-Aug	7:46:25	Blue	40	43
22-Aug	7:49:28	Blue	40	43
22-Aug	16:38:10	Blue	40	43
22-Aug	18:03:03	FL Green	21	23
22-Aug	2:35:05	Pink	33	36
22-Aug	7:43:23	U		
22-Aug	2:29:19	U (brown?)		
22-Aug	7:35:04	U (brown?)		
22-Aug	19:13:48	U (brown?)		
22-Aug	21:34:00	U (brown?)		
23-Aug	7:47:59	Blue	41	44
23-Aug	21:30:21	Blue	41	44
23-Aug	10:28:30	Pink	34	37
23-Aug	16:35:52	Pink	34	37
23-Aug	22:22:06	U		
23-Aug	4:23:06	U (brown?)		
24-Aug	0:07:23	green	23	25
24-Aug	5:31:48	green	23	25
25-Aug	19:05:49	Brown	29	32
25-Aug	23:59:09	U (brown?)		
26-Aug	21:51:42	Pink	37	40
26-Aug	21:59:10	U (brown?)		
26-Aug	22:05:29	White	9	18
27-Aug	2:08:16	Brown	31	34
27-Aug	5:31:35	Brown	31	34
27-Aug	5:04:19	green	26	28
27-Aug	2:00:56	U		
28-Aug	1:58:57	Pink	39	42
30-Aug	22:14:00	green	29	31
10-Sep	1:13:06	Pink	52	55
11-Sep	2:03:12	White	25	34
13-Sep	5:22:14	White	27	36
14-Sep	3:47:28	FL Green	44	46
19-Sep	0:03:05	White	33	42

NOTE: Most unknowns are likely brown as this was a difficult color to identify

APPENDIX D

Digital video equipment list

Table D-1. Kwinagese River Video System Components and Cost in 2002

Component	Make	Model	Cost each	Rating	Comment
Digital Video Recorder	Silent Witness	DVMS 1600	$8,000.00	Excellent	Faulted once in 90 days of continuous operation
Hard Disks (120 gigabyte)	Western Digital	WD1200	$320.00	Excellent	Storage of 10 days of high quality video
Video Chamber	Custom		$1,200.00	Good	needs improvements to enhance lighting
Camera (Color)	Extreme CCTV	EX10	$600.00	Poor	good video quality but leaked at 1 m depth
Camera (Color)	Micro-Video	MVC2120-WP	$550.00	Good	good video quality, fragile housing and cable
Camera (Monochrome)	Micro-Video	MVC2000-WP	$340.00	Good	good video quality, fragile housing and cable
Camera (Color)	Integrated Aqua Systems	SeeMate	$1,150.00	Fair	sensitive to electrical noise from battery charging
Camera (Monochrome)	Integrated Aqua Systems	SeeMate	$875.00	Excellent	good vodeo quality, very robust housing and cable
Photoswitch (12-volt)	Alternative Energy Engineerin	PC-20	$110.00	Very Good	One unit failed
Batteries (6-volt)	Genaric	industrial	$95.00	Very Good	
Battery Charger	Motomaster	70/12/2 A Manu:	$110.00	Excellent	
Light (20-watt halogen)	Little Giant	Pond Glow	$90.00	Good	
Light (8-watt flourescent)	Pit Stop	Work Light	$20.00	Good	
Light (35-watt halogen)	Blazer	120	$15.00	Poor	

PHOTO PLATES

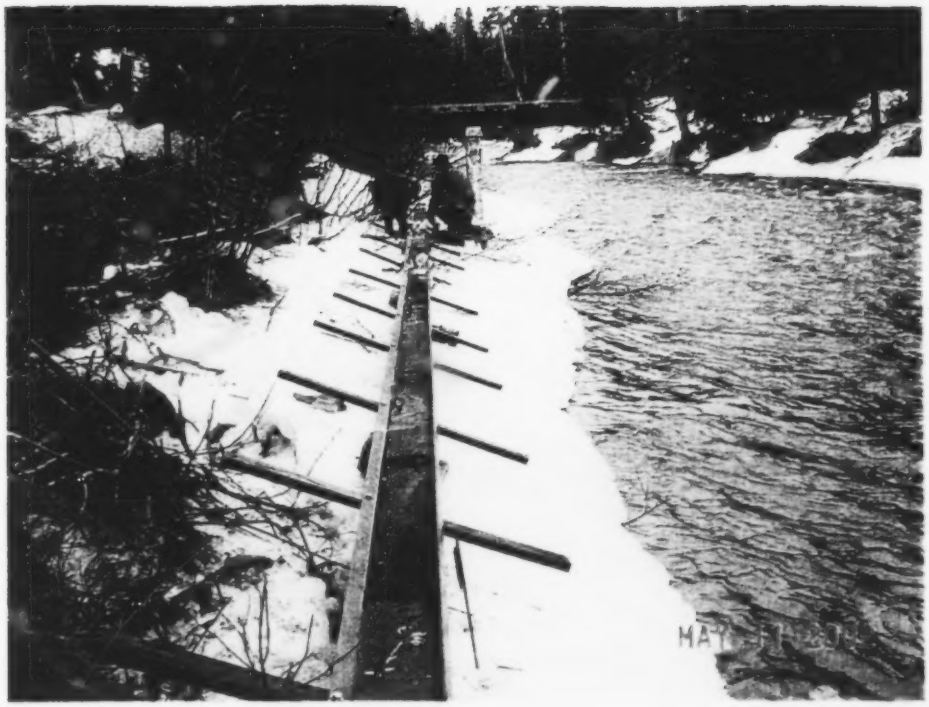

Photo 1. Complete sill rail/track before installation.

Photo 2. Sill rail/track with trolley.

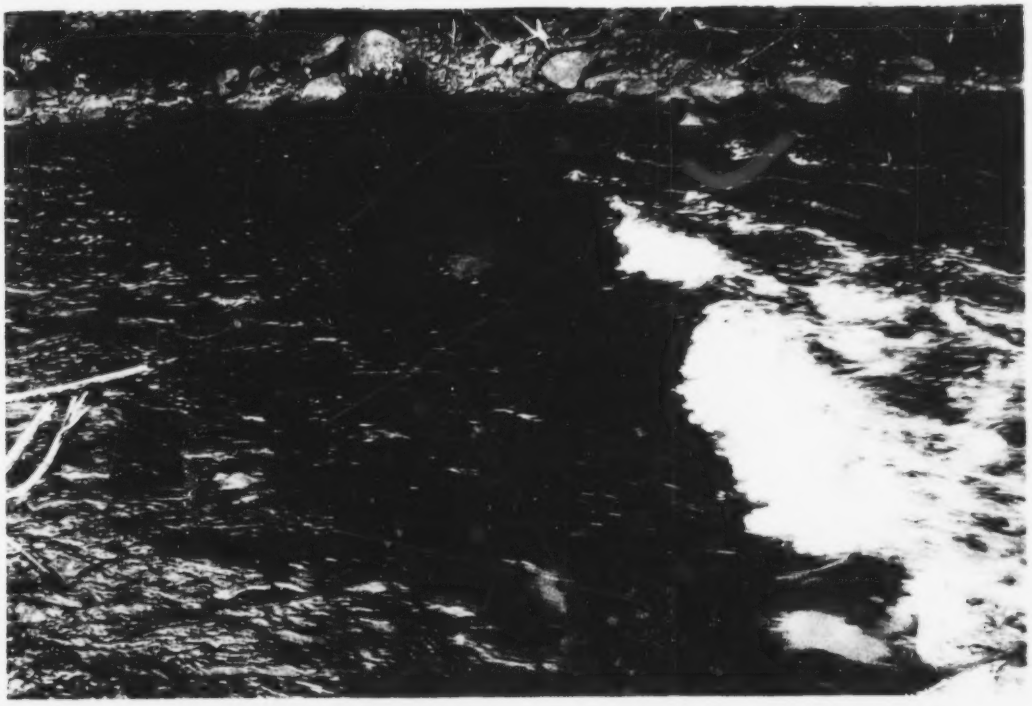

Photo 3. Sill rail/track installed in river at extreme low flow after weir removal.

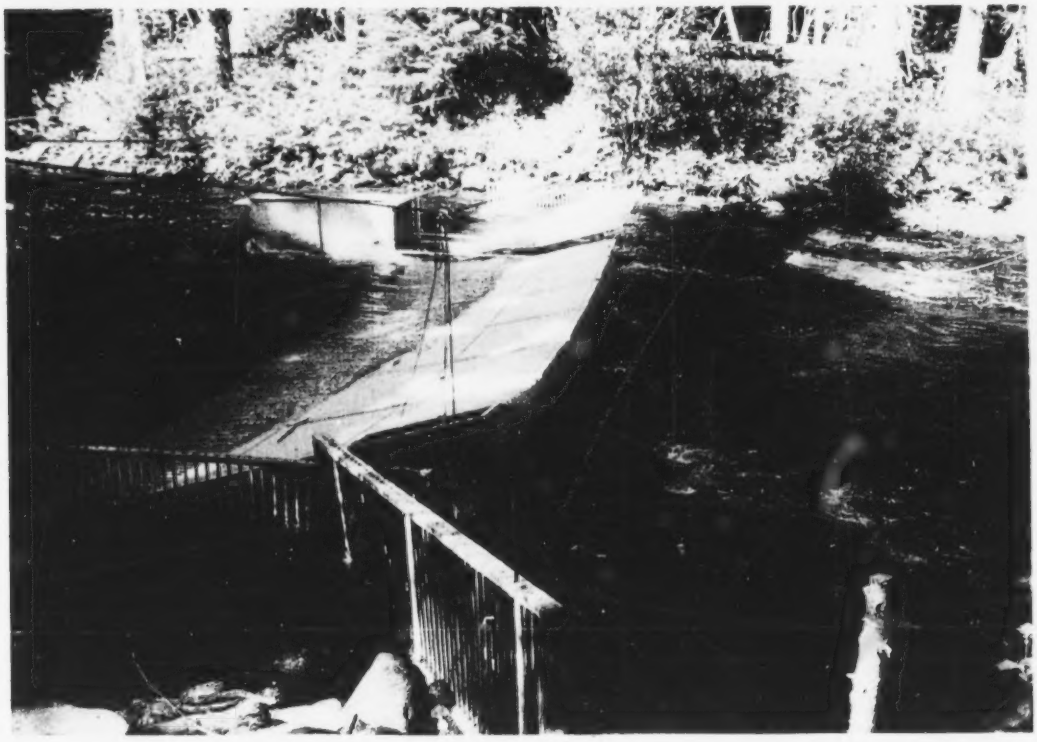

Photo 4. Kwinageese fence and video view box at low water.

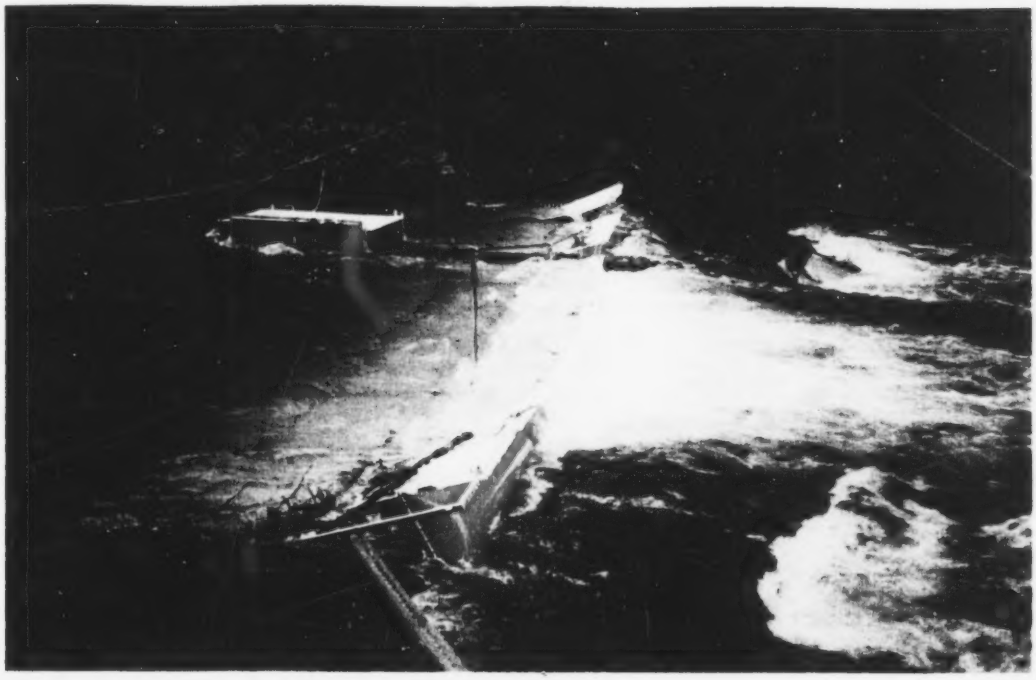

Photo 5. Kwinageese fence and video box at high water.

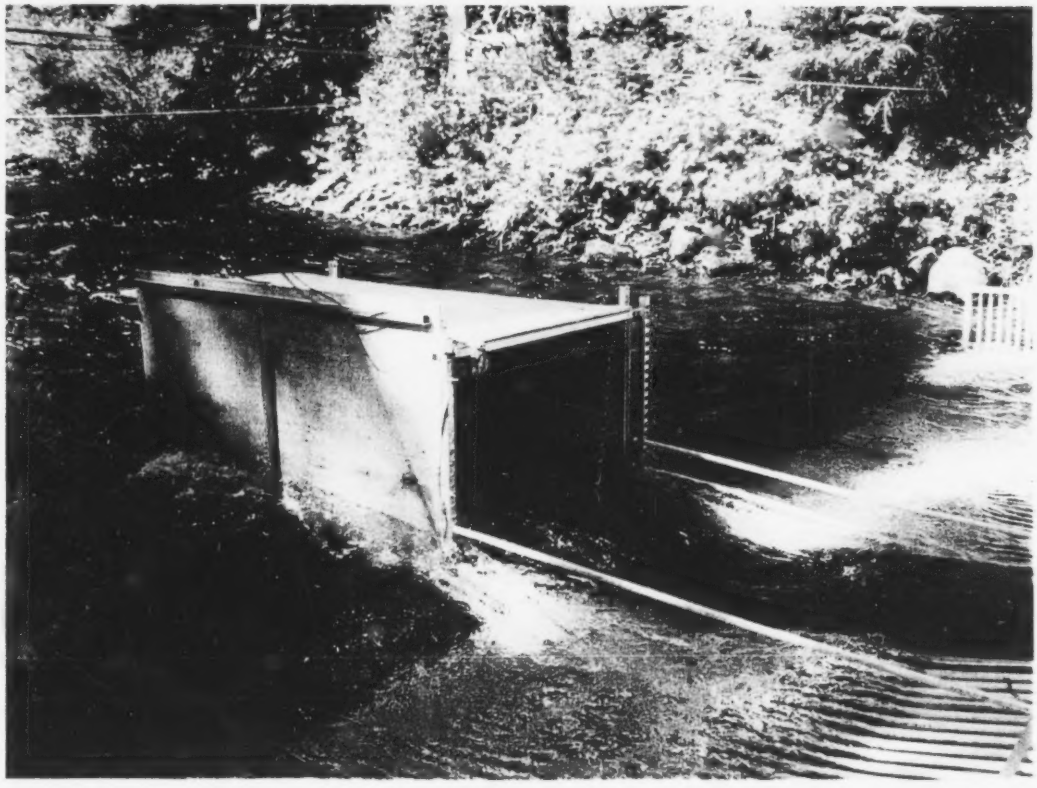

Photo 6. Video view box, upstream view.

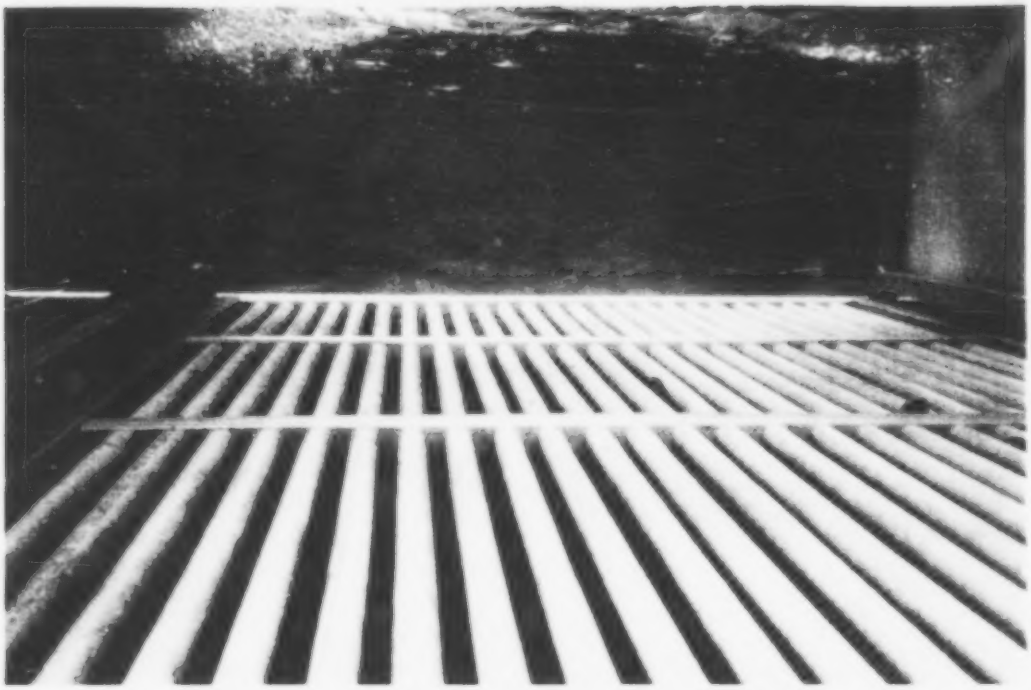

Photo 7. Video view box, upstream underwater view.

Photo 8. Video viewing operation at Kwinageese River in 2002.

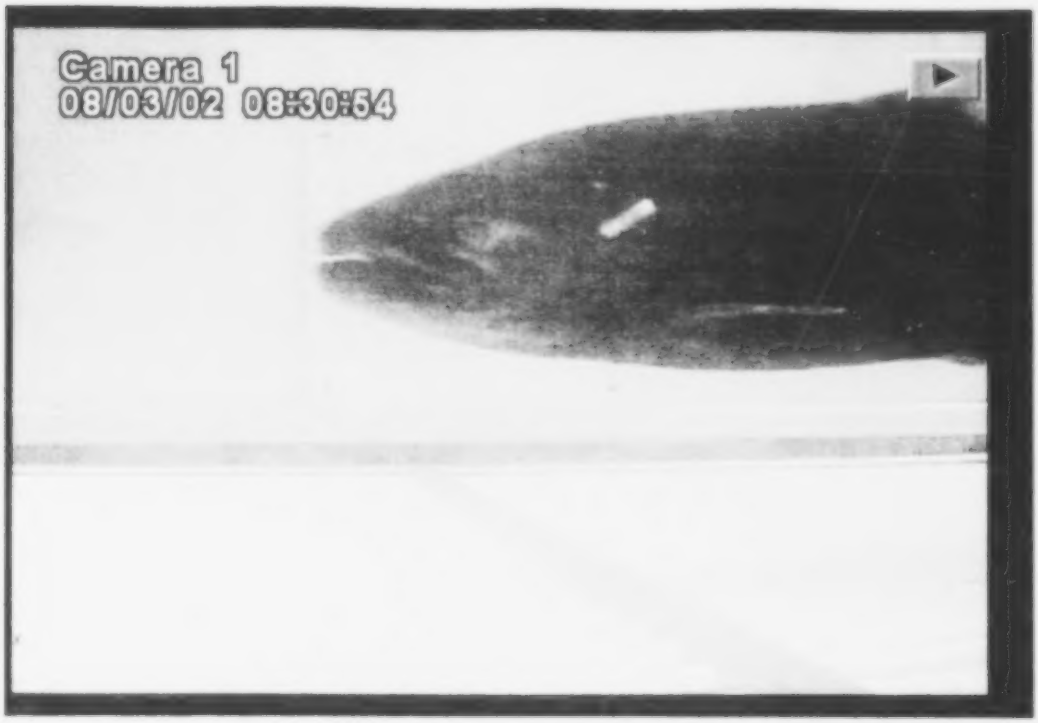

Photo 9. Video frame of tagged chinook salmon.

Photo 10. Video frame of sockeye in video view box.

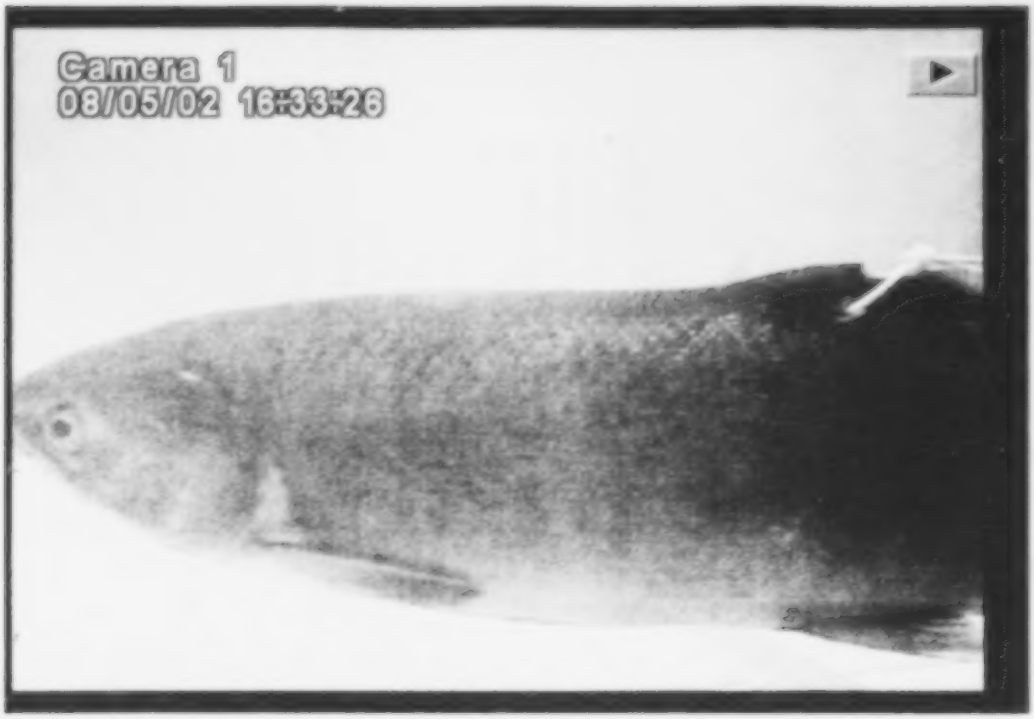

Photo 11. Video frame of sockeye with yellow spaghetti tag.

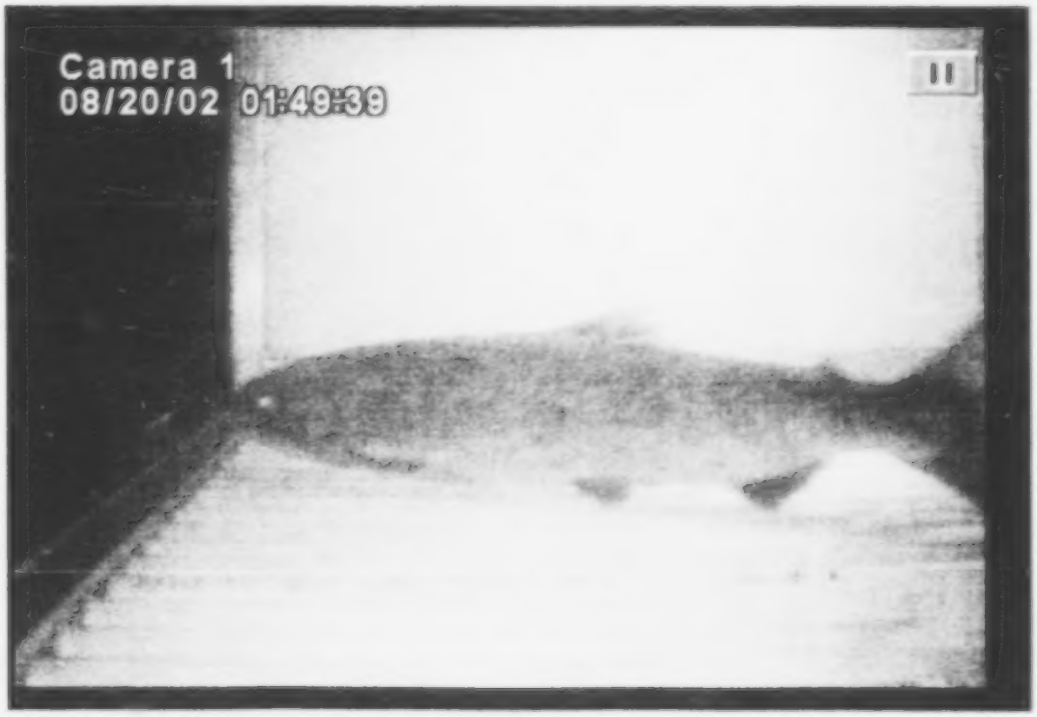

Photo 12. Video frame of sockeye salmon with pink spaghetti tag, at night, under poor lighting conditions.